FLORA AND VEGETATION OF THE MOHAWK DUNES, ARIZONA

Richard Stephen Felger
Drylands Institute
2509 North Campbell, #405
Tucson, AZ 85719, U.S.A.
rfelger@drylands.org

Dale Scott Turner
The Nature Conservancy
1510 E. Fort Lowell
Tucson, AZ 85719, U.S.A.

Michael F. Wilson
Drylands Institute
2509 North Campbell, #405
Tucson, AZ 85719, U.S.A.

ABSTRACT

One-hundred twenty-two species of seed plants, representing 95 genera and 35 families are documented for the 7,700 ha Mohawk Dune Field and its immediate surroundings, located in Yuma County, Arizona, USA. Three major habitats were studied: dunes, adjacent sand flats, and playa. The dunes (including interdune swales) support 78 species, of which 13 do not occur on the adjacent non-dune habitats. The adjacent non-dune habitats (sand flats and playa) support 109 species, of which 43 were not found on the dunes. The total flora has 81 annual species, or 66% of the flora. The dune flora has 63 annual (ephemeral) species, or 81% of the flora—one of the highest percentages of annuals among any regional flora. Of these dune annuals, 53 species (84%) develop during the cool season. No plant taxon is endemic to the Mohawk region. There are 8 dune, or sand adapted, endemics—*Cryptantha ganderi, Dimorphocarpa pinnatifida, Dicoria canescens, Ditaxis serrata, Pleuraphis rigida, Psorothamnus emoryi, Stephanomeria schottii, Tiquilia plicata*—all of which are found on nearby dune systems. Two of them (*C. ganderi* and *S. schottii*) are of limited distribution, especially in the USA, and have G2 Global Heritage Status Rank. There are four non-native species in the dune flora (*Brassica tournefortii, Mollugo cerviana, Sonchus asper, Schismus arabicus*), but only *Brassica* and *Schismus* seem to pose serious threats to the dune ecosystem at this time. The Mohawk Dune field is within the Lower Colorado Valley phytogeographic region of the Sonoran Desert and located within the Barry M. Goldwater Military Range. This unique dune system, largely unaffected by human activities, is recommended as a site for baseline studies of plant migrations and population dynamics affected by global climatic change.

RESUMEN

Ciento veintidos especies de espermatófitos, que representan 95 géneros y 35 familias se documentan para las 7.700 ha del Mohawk Dune Field y sus alrededores, en el condado de Yuma, Arizona, USA. Se estudiaron tres grandes hábitats: dunas, arenales planos, y playas. Las dunas (incluyendo las depresiones interdunares) tienen 78 especies, de las que 13 no se dan en los hábitats no dunares adyacentes. Los hábitats adyacentes no dunares (arenales planos y playa) tienen 109 especies, de las que 43 no se encontraron en las dunas. La flora total tiene 81 especies anuales, o el 66% de la flora. La flora dunar tiene 63 especies anuales (efímeras), o el 81% de la flora—uno de los porcentajes más altos de anuales en las floras regionales. De estas anuales dunares, 53 (84%) se desarrollan durante la estación fría.

DUNE SYSTEMS AND ENVIRONMENT

Dunes inspire thoughts of barren desert, windblown and inhospitable. Yet dunes can support substantial and unique plant life. Sand dunes occur around the globe

SIDA 20(3): 1155–1187. 2003

as both coastal and inland systems, and are not restricted to deserts but are often prominent features of major deserts. Dunes are relatively rare in the Americas, covering about 0.5% of the arid zones in North America (Bowers 1982, 1984). The major Sonoran Desert dune fields are the Gran Desierto Dunes of northwestern Sonora and the related Algodones Dunes of southeastern California. Hot-desert dune plant communities must cope with an array of challenging growth conditions, including burial, root exposure, wind shear, and low nutrient levels. As a result, dune floras are frequently characterized by high levels of endemism and specialized adaptations (Bowers 1982). Despite these challenges, Shreve (1951:127) pointed out that "Sand...is a particularly favorable soil for the ephemerals of the cool season, because of the deep infiltration of moisture and the rapid warming of the surface early in the season and early in the day."

This publication reports the composition and characteristics of the flora and vegetation of the Mohawk Dunes, reflecting accumulated data from numerous visits to the area by the authors spanning more than five years, as well as herbarium records of other collectors. The first section describes dune systems and the physical environment, management, and global significance of the Mohawk Dunes in particular. The second section is a description of the Mohawk Dune vegetation and flora, and the third catalogues its flora, containing species accounts for each of the 123 species of the dune system and the immediately adjacent desert flats.

PHYSICAL CHARACTERISTICS OF THE MOHAWK DUNES

The Mohawk dune field is located about 65 km east of Yuma, Arizona, on the eastern side of the Mohawk Valley in Yuma County (Broyles et al. 1997). The region is within the Lower Colorado Valley phytogeographic subdivision of the Sonoran Desert (Shreve 1951). The Mohawk Valley is roughly 28 km wide, forming a nearly flat plain with moderately sandy soils. Steep, rocky mountain fronts bound the valley to the east and west, similar plains stretch far to the south, and the north end is bounded by agricultural fields along the now usually dry Gila River. The valley lacks any well-defined central drainage channel, with the mountain fronts draining into ephemeral stream channels, which rapidly shrink to insignificance. The elongated dune system runs parallel to, and west of the Mohawk Mountains, trending northwest to southeast (Fig. 1). Small, scattered outlier dunes occur in the San Cristobal Valley east of a pass in the Mohawk Mountains. The Mohawk dune field is about 32 km long and varies in width up to 3.2 km wide, covering approximately 7,770 ha. Maximum elevation is 207 m near the center of the dunes, rising about 55 m above the surrounding desert. The underlying desert floor rises gently from an elevation of 116 m at the north end of the dunes to 192 m at the south end (Smith & Bender 1973).

The dune contours consist of a fairly regular series of depressions surrounded

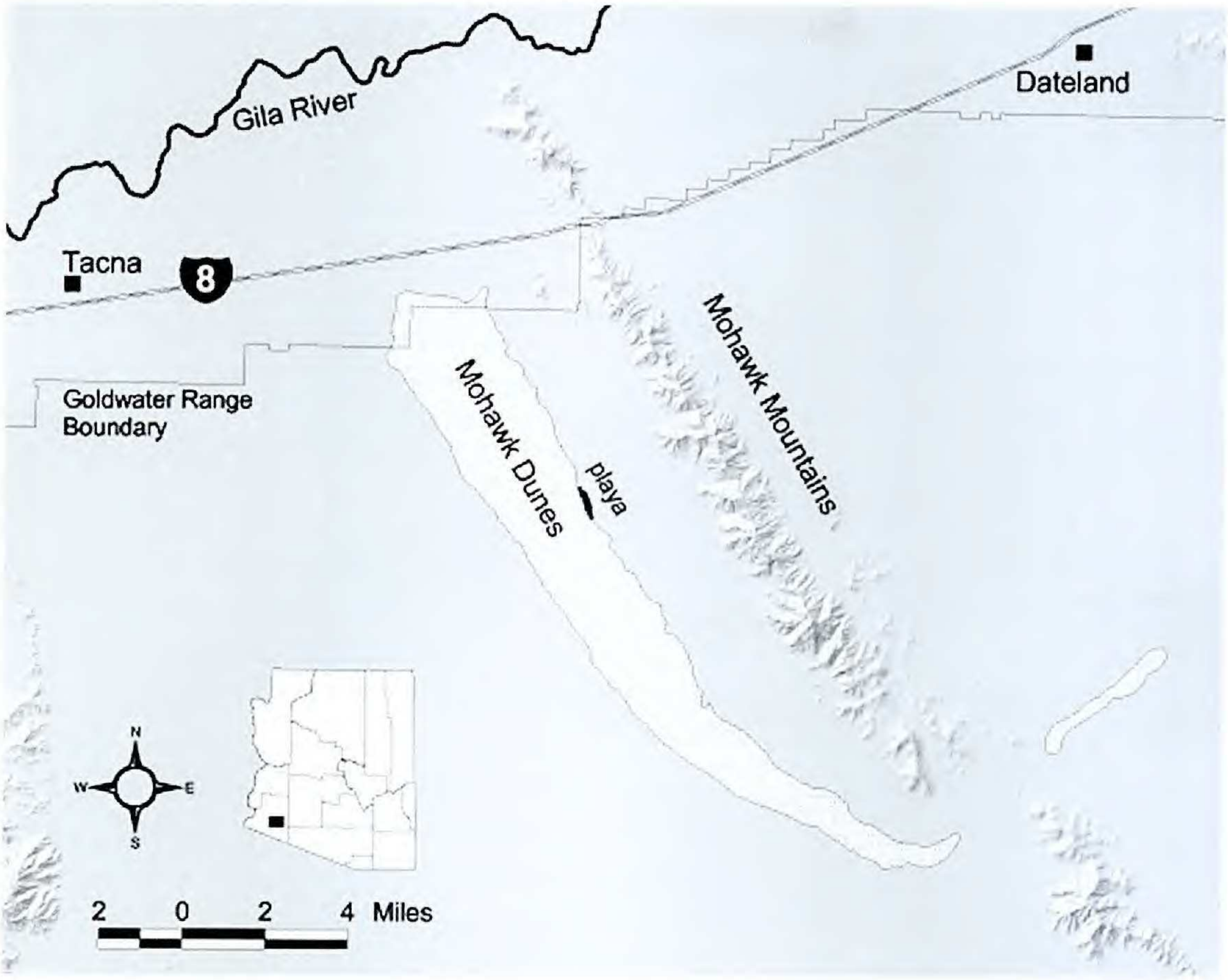

Fig. 1. Location of Mohawk Dunes in southwestern Arizona.

by ridges, resembling a honeycomb in aerial view. Swales—low areas between dunes—and the surrounding crests form microhabitats with significantly different plant and animal communities. The crests are characterized by shifting or slightly stabilized sands and a dominance of sand-adapted species. In contrast, the swales have soil textures and species assemblages that more closely resemble the desert surrounding the dune field (Turner et al. 1997a). The swales are also notable for having a much more stable surface. This is largely maintained by a well-developed microbiotic crust dominated by the cyanobacterium *Microcoleus vaginatus* and the lichen *Collema* sp. (Jane Belnap, pers. comm.).

The Mohawk Dune system appears to have been in place for an extended period. Extensive layers of calcium carbonate are evident on swale slopes, and we have found numerous fossil remnants of tortoises and other vertebrates. The dune sand is composed mainly of quartz and feldspar. According to Bowers (1986:57), "... the Mohawk Dunes have garnered all the sand available for their formation: no more sand is being blown into the dune field." It seems reasonable to suspect that an earlier configuration of the Gila River was the source of sand for these dunes, but that question remains unstudied.

A distinctive playa (the bed of an ephemeral lake), 1,400 m × 250 m, lies along the eastern side of the dunes, about 8 km south from the dune field's north end (Fig. 1). It appears to fill to a depth of <1 m with a frequency of about once per decade, most recently in winter 1992–93. Its more common aspect features sun-baked clay with an extensive network of deep cracks.

Climate

Air temperature regimes for the area are typical of the lower Sonoran Desert, with mean daily maxima of 40-43°C for June through September, and peaks in excess of 49°C during midsummer (Sellers & Hill 1974). Surface temperatures on the dunes reach greater extremes, with June and July maxima averaging above 65°C in 1996. Relative humidity is generally low, dropping below 10% on most days in the summer and many days in winter (Turner, unpubl. data).

Annual rainfall averaged 10.54 cm from 1900-1951 at the nearest weather station, Mohawk, ca. 5 km northeast from the north end of the dune field. About half of the annual total, 4.85 cm, fell during the May-October warm season, primarily during July-September, while 5.72 cm fell November-April (Sellers et al. 1985). Months with no rain are common, and summer storms can deliver a large fraction of the total annual precipitation in a short period (Sellers & Hill 1974).

Although rainfall data from nearby stations may be indicative of regional trends and normal year-to-year variation, they may not provide accurate data on local precipitation. A six-year study in Yuma showed that summer rainfall can vary by more than 2.5 cm for sites only 1.6 km apart (Turnage & Mallery 1941). Rain gauges at the Mohawk Dunes separated by 9.3 km recorded 2.54 and 0.38 cm for the same period of August through October 1994. The same two gauges recorded 0.46 and 3.30 cm respectively for a single storm event in July 1996 (Turner, unpubl. data). Such variation can cause dramatic differences in vegetative composition and abundance between sites.

Mohawk Dunes as a Long-Term Research Site

The Mohawk Dunes and surrounding landscape are part of the Barry M. Goldwater Military Range, jointly managed by 56th Range Management Office at Luke Air Force Base and the Range Management Department at Marine Corps Air Station, Yuma (Felger et al. 1997; Tunnicliff et al. 1986). The western part of the range including the Mohawk Dunes is managed by the Marine Corps and lands to the east are managed by the Air Force. Civilian access requires permission from the military. Military activities have impacted only approximately 5-12% of the entire 690,000 ha Goldwater Range and have had very little apparent affect on the dune biota. To date the military has provided substantial protection from the damaging recreational activities common to other dune systems in the American Southwest, and the Mohawk Dunes remain largely unaffected by human activity. However, future military and civilian effects on the dunes will be determined by management plans now under discussion.

The dunes are a popular destination for the public during spring wildflower displays, and there is occasional illegal off-road driving. Planning should assure undisturbed areas for monitoring and research, while other areas have access but with precautions to insure minimal impact.

Our understanding of global diversity is hindered by the lack of knowledge of changes in species composition over time so that processes of colonization, extinction, and evolution cannot be thoroughly described. This underlines the importance of maintaining areas that remain undisturbed by human development and that have protected status or the potential for protection due to land ownership. The manageable size of the Mohawk Dunes makes them an excellent candidate as a long-term research site. Careful stewardship of the dune field will serve to protect their value to our understanding of ecosystem processes.

METHODS

This report reflects accumulated data from numerous trips to the area with primary collections during 1995-1998. Specimens are at ARIZ, with duplicates for most species variously going to other herbaria, e.g., ASU, RSA, SD, and the Yuma District Office of the Bureau of Land Management. We also examined additional specimens, primarily at ARIZ, ASU, and RSA.

As part of an ecological inventory and monitoring program (Turner et al. 1997 a, b), plant cover sampling was done at two sites in the dune system using a stratified random sampling design to characterize the crest and swale plant communities. This involved randomized placement of quadrats along curvilinear transects which stayed either on crests or in swales, along transects which were previously established for a lizard monitoring program. Dune crests were sampled with a 1-km transect at a site on the east side of the dunes near the playa and two 500-m transects on the west side. Swales were sampled with a single 1-km transect near the playa.

We used quadrats 0.5 × 2 m, to take 200 samples out of a 10-m-wide swath along each 1-km transect, or 100 samples for each 500-m transect, for a representative sample of 1 ha for each sample site. Sampling was conducted during March 1996, following an unusually dry year, and thus measured almost exclusively perennial species.

VEGETATION AND FLORA

The total flora of the Mohawk Dune Region (dune and non-dune habitats) is comprised of 122 vascular plant species in 95 genera and 35 families. The most diverse families are the Asteraceae, Fabaceae, Poaceae, and Brassicaceae (Table 1). The most diverse genera are *Camissonia* with 4 species and two subspecies, *Cryptantha* with 4 species, and *Ambrosia* and *Boerhavia* each with 3 species. The growth-form spectrum is shown in Fig. 2. The different life forms are more or less evenly distributed between the dunes and sand flats except that all but one (*Prosopis*) of the tree and large-shrub species (microphanerophytes) are absent from the dunes (Table 2). The total flora has 81 annual or ephemeral species, or a remarkable 66% of the flora (see discussion below for dunes). In contrast the ephemeral/annual flora of northwestern Sonora comprises 46% of the total flora, and across much of the Sonoran Desert the ephemerals make up about 50% of the total flora (e.g., Felger 2000; Venable & Pake 1999).

During the warmer months, often April and early May, and again with summer-early fall rains, many of the common ephemerals can be ravaged by caterpillars of the white-lined sphinx moth (*Hyles lineata*) (Fig. 10). Plants favored by these caterpillars include *Allionia incarnata*, *Boerhavia* spp., *Euphorbia abramsiana*, *Kallstroemia californica*, *Lupinus arizonicus*, and *Pectis papposa*.

Vegetative cover by perennial plants

Vegetative cover data were gathered during an unusually dry spring. Eight plant species were found living in 600 quadrats. We found almost no annual plants at that time. Mean ground cover on the dune crests ("dunes") ranged from 7-15%, while that in the swales was about 9% (Table 3). Dominant perennial species on the crests included *Ambrosia dumosa*, *Aristida californica*, *Ephedra trifurca*, *Pleuraphis rigida*, and *Psorothamnus emoryi*. The swales had a similar suite of species, with the addition of *Larrea divaricata* and a strong reduction in *Psorothamnus emoryi*.

Habitats

Bowers (1982) found that plant communities on dunes are mixtures of dune endemics, widely distributed plants of sandy soils, and plants found in adjacent, non-dune habitats. The desert flats, or sand flats, and the small playa are the non-dune habitats adjacent to the Mohawk Dunes.

Dunes.—During years of favorable winter-spring rainfall, such as certain El Niño years, the dunes support spectacular displays of wildflowers. Among the most conspicuous are sand verbena (*Abronia villosa*), desert marigold (*Baileya* spp.), desert cryptantha (*Cryptantha angustifolia*), spectaclepod (*Dimorphocarpa pinnatifida*), Arizona lupine (*Lupinus arizonicus*), evening-primrose (*Oenothera deltoides*), and Spanish needles (*Palafoxia arida*). Notably prominent are plants with dense whitish- or silvery-haired leaves and stems, e.g., *Ambrosia dumosa*, *Dicoria canescens*, and *Psorothamnus emoryi*. Deep roots are likewise a common feature, enabling plants to utilize moisture deep in the sand.

The floristic makeup of the dune communities, particularly among perennial species, is highly predictable, with relatively little change in species com-
Psorothamnus emoryi, *Tiquilia plicata*; Ephemerals—*Abronia villosa*, *Dicoria canescens*, *Dimorphocarpa pinnatifida*, *Lupinus arizonicus*, *Oenothera* plants
higher, shifting (moving or unstable) dunes are: Perennials—*Ambrosia dumosa*,

Table 1. Four largest families.

Family	Genera	Species
Asteraceae	17	21
Fabaceae	9	11
Poaceae	7	9
Brassicaceae	7	7

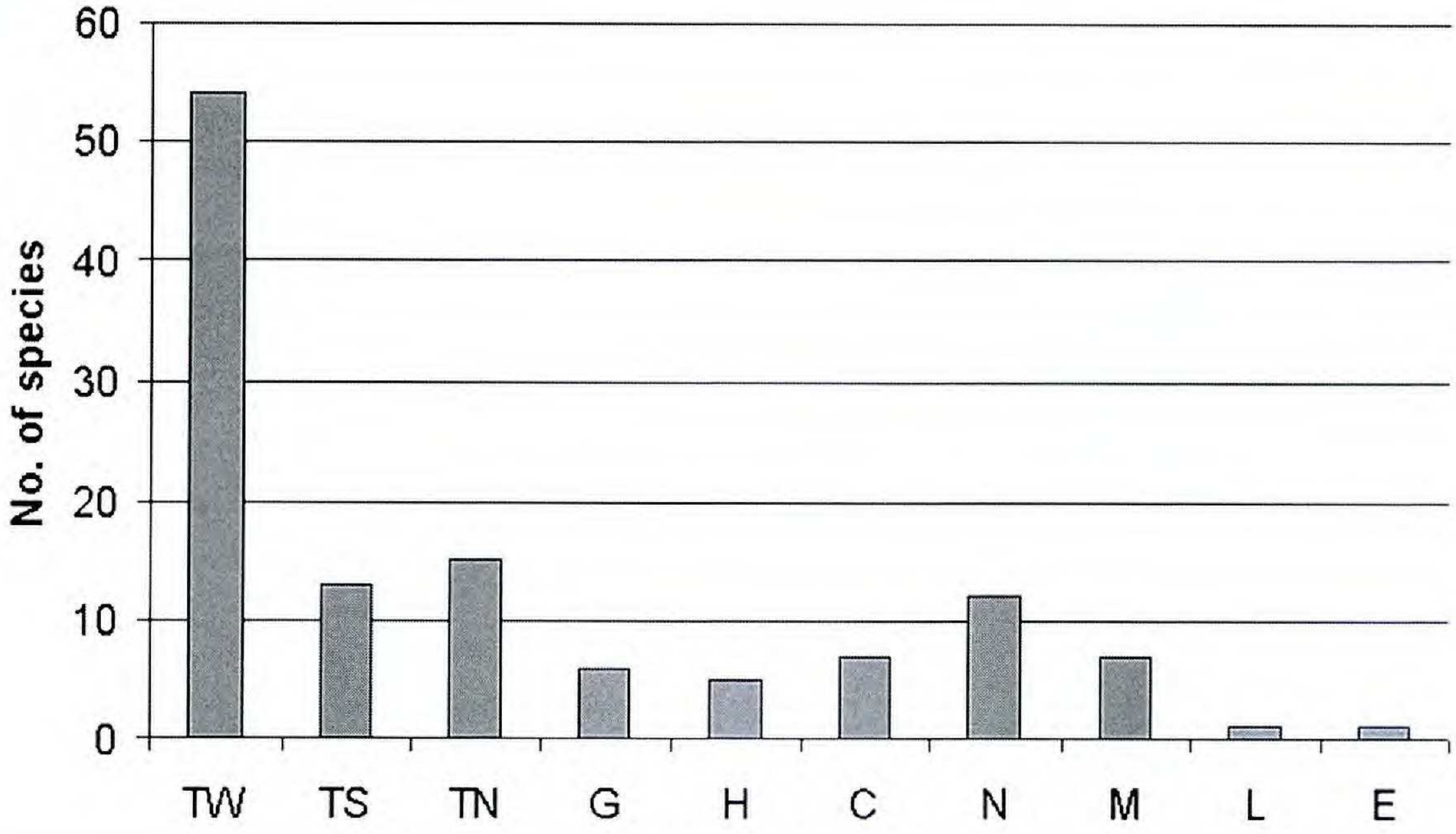

Fig. 2. Life-form spectrum of the Mohawk flora. **TW** = winter-spring or cool-season therophytes (annuals or ephemerals); **TS** = summer or hot-season therophytes; **TN** = non-seasonal therophytes; **G** = geophytes (perennials with meristem below ground); **H** = hemicryptophytes (perennials with meristem [growth bud] at or near the soil surface; **C** = chamaephytes (perennials with meristem above ground but usually less than 0.5 m tall); **N** = nanophanerophytes (shrubs or shrub-sized perennials, usually 0.5–2 m tall); **M** = microphanerophytes (trees or shrubs usually 2–8 m tall); **L** = perennial liana or vine; **E** = epiphyte.

position across the dune fields. Among the most common and conspicuous on *Aristida californica*, *Ephedra trifurca*, *Pleuraphis rigida*, *deltoides*, *Stephanomeria schottii*, and many others. Characteristic common plants on low, partially stabilized dunes as well as other sandy habitats include: Perennials—*Ambrosia dumosa*, *Aristida californica*, *Larrea divaricata*, *Pleuraphis rigida*, *Tiquilia palmeri*; Ephemerals—*Abronia villosa*, *Brassica tournefortii*, *Eriogonum trichopes*, *Oenothera primiveris*, *Schismus arabicus*, *Stephanomeria schottii*, and many others.

The dunes support 78 species, of which 13 do not occur on the adjacent non-dune habitats (Table 2). The dune flora includes 63 annual or ephemeral

TABLE 2. Distribution of the Mohawk Flora for three habitat types with growth-forms. See Fig. 2 for explanation of life-form symbols (p = parasitic plants; s = succulent plants). Very rare occurrences or extirpated species shown in parenthesis (-).

	dunes	Sandflats	playa	Growth form
Abronia villosa	D	S		TW
Achyronychia cooperi	D	S		TW
Allionia incarnata	D	S		TN
Amaranthus fimbriatus	D	S		TS
Amaranthus palmeri		S		TS
Ambrosia confertiflora		S		H
Ambrosia deltoidea	D	S		C
Ambrosia dumosa	D	S		C
Amsinckia tessellata	D	S		TW
Argemone gracilenta	D			H
Aristida adscensionis		S		TN
Aristida californica	D	S		H
Asclepias subulata		S		Ns
Astragalus insularis	D	S		TW
Astragalus nuttallianus	D	S		TW
Baccharis salicifolia			(P)	N
Baccharis sarothroides			(P)	N
Baileya pauciradiata	D	S		TW
Baileya pleniradiata	D	S		TN
Boerhavia erecta		S		TS
Boerhavia spicata	D	S		TS
Boerhavia wrightii		S		TS
Bouteloua aristidoides	D	S		TS
Bouteloua barbata	D	S		TS
Brassica tournefortii	D	S		TW
Camissonia boothii		S	(P)	TW
Camissonia californica	D	S		TW
Camissonia chamaenerioides		S		TW
Camissonia claviformis ssp. *peeblesii*	D	S		TW
Camissonia claviformis ssp. *Yumae*		S		TW
Carnegiea gigantea		(S)		Ms
Castela emoryi		S		M
Caulanthus lasiophyllus	D	S		TW
Chaenactis stevioides	D	S		TW
Chorizanthe brevicornu	D	S		TW
Chorizanthe rigida		S		TW
Cylindropuntia echinocarpa	D	S		Ns
Cryptantha angustifolia	D	S		TW
Cryptantha ganderi	D			TW
Cryptantha maritima		S		TW
Cryptantha micrantha	D			TW
Cuscuta umbellata	D	S		TSp
Dalea mollis	D	S		TN

TABLE 2. continued

	dunes	Sandflats	playa	Growth form
Datura discolor	?	S		TN
Dicoria canescens	D			TN
Dimorphocarpa pinnatifida	D			TW
Ditaxis serrata	D	S		TN
Dithyrea californica	D			TW
Echinocactus polycephalus		(S)		Cs
Ephedra trifurca	D	S		N
Eriastrum diffusum	D	S		TW
Eriastrum eremicum		S		TW
Eriogonum trichopes	D	S		TW
Eriophyllum lanosum		S		TW
Erodium texanum		S		TW
Eschscholzia glyptosperma		S		TW
Eschscholzia minutiflora	D	S		TW
Euphorbia abramsiana	D	S		TS
Euphorbia polycarpa	D	S		TN
Ferocactus wislizeni	(D)	S		Ns
Filago arizonica		S		TW
Festuca octoflora		S		TW
Fouquieria splendens		S		M
Funastrum cynanchoides		S		L
Geraea canescens	D	S		TW
Grusonia kunzei		(S)		Cs
Heliotropium convolvulaceum	D			TN
Heliotropium curassavicum			P	G
Hesperocallis undulata	D	S		G
Hoffmannseggia glauca			P	G
Isocoma acradenia		S	P	C
Kallstroemia californica	D	S		TS
Krameria erecta		S		C
Krameria grayi		S		N
Larrea divaricata	D	S		N
Lepidium lasiocarpum	D	(S)		TW
Linanthus bigelovii	D	S		TW
Loeseliastrum schottii	D	S		TW
Lupinus arizonicus	D	S		TW
Lycium parishii		S		N
Malacothrix glabrata	D			TW
Malvella sagittifolia			P	G
Marina parryi	D	(S?)		TN
Mentzelia albicaulis	D			TW
Mentzelia multiflora	D	S		TW
Mollugo cerviana	D			TS
Monoptilon bellioides	D	S	(P)	TW
Muhlenbergia microsperma		S		TN

TABLE 2. continued

	dunes	Sandflats	playa	Growth form
Nama hispidum	D	S	(P)	TW
Nemacaulis denudata	D			TW
Oenothera deltoides	D	S		TW
Oenothera primiveris	D	S		TW
Oligomeris linifolia	D	S	P	TN
Olneya tesota		S		M
Orobanche cooperi		S		TWp
Palafoxia arida	D	S		TN
Panicum alatum		S		TS
Parkinsonia florida		S		M
Parkinsonia microphylla		S		M
Pectis papposa	D	S		TS
Pectocarya heterocarpa	D	S		TW
Pectocarya platycarpa	D	S		TW
Phacelia ambigua		S		TW
Phoradendron californicum		S		Ep
Physalis lobata			P	H
Physaria tenella		S		TW
Plantago ovata	D	S	P	TW
Pleuraphis rigida	D	S		H
Populus fremontii			(P)	N
Proboscidea altheaefolia	D	S	P	G
Prosopis glandulosa	D	S	P	M
Psorothamnus emoryi	D			N
Rafinesquia neomexicana	D	S		TW
Schismus arabicus	D	S		TW
Sonchus asper	D	S		TW
Sphaeralcea ambigua		(S)	P	C
Sphaeralcea coulteri	D	S		TN
Stephanomeria schottii	D			TW
Streptanthella longirostris	D	S		TW
Stylocline micropoides	D	S		TW
Tamarix ramosissima			(P)	N
Tidestromia lanuginosa	D	S		TS
Tiquilia plicata	D	(S)		G
TOTALS: 122 species.	78	101	17	

species, representing 81% of the dune flora, one of the highest percentages of annuals among any regional flora. Of these dune ephemerals, 53 species, or 84% develop during the cool season (41 winter/spring and 12 non-seasonal species), which supports Shreve's (1951:127) statement that sand is a favorable soil for cool-season ephemerals. Non-seasonal ephemerals are those that can germinate and grow with sufficient soil moisture at any time of year (see Felger 2000). Variation in plant cover and dune vegetation is shown in Figs. 3–5.

TABLE 3. Average percent ground cover at three localities in the Mohawk Dunes, March 1996.

Species	E-side dune	E-side swale	W-side dune
Ambrosia dumosa	1.56	4.14	9.07
Aristida californica	0.00	0.89	1.28
Ephedra trifurca	0.97	1.12	1.30
Larrea divaricata	0.00	1.16	0.00
Pleuraphis rigida	3.35	1.41	3.50
Psorothamnus emoryi	0.89	0.24	0.08
Tiquilia plicata	0.01	0.00	0.01
Lupinus arizonicus	0.01	0.01	0.02
Total live ground cover %	6.77	8.95	15.25

Playa.—The main expanse of the playa consists of silty-clay soil riddled with deep fissures. Seventeen species were found on the playa and its margins. Three herbaceous root-perennials are abundant across the expanse of the playa: *Heliotropium curassavicum*, *Hoffmannseggia glauca*, and *Malvella sagittifolia*. Following the occasional times when the playa fills with water, *Sphaeralcea ambigua* and other herbaceous plants may become locally abundant. *Physalis lobata*, *Oligomeris linifolia*, and *Prosopis glandulosa* are locally common around the margin of the playa. The remaining species are uncommon in this habitat or on sandy soils at the playa margin. Four woody plants are known from one or few individuals that probably germinated during the exceptionally wet year of 1992–93: seep willow (*Baccharis salicifolia*), desert broom (*B. sarothroides*), cottonwood (*Populus fremontii*), and tamarisk (*Tamarix ramosissima*). The cottonwood and seep willow perished from drought by the end of 1994 and the tamarisk by June 1996.

Sand flats. Areas surrounding the dune field vary from rolling hills and low sand hummocks to occasionally extensive flats of sandy to silty-sand and clay-sand soils. These habitats, collectively called "sand flats," support 101 species within ca. 1 km of the dune margins (Table 2). Nearly 30% of these species were not found on the dunes.

Desert shrubs, namely creosotebush and the two bursages (*Ambrosia deltoidea* and *A. dumosa*) are the most common, widespread elements in the landscape. Several cacti and crucifixion thorn (*Castela emoryi*) are widely but thinly scattered across the landscape, and patchy areas of ocotillo (*Fouquieria splendens*), ratany (*Krameria erecta*), and several other perennials are locally prominent.

The sand flat habitats and vegetation grade into those of the dunes, and less noticeably into the surrounding valley plains and vegetation. But common shrubs such as creosotebush (*Larrea divaricata*) tend to be noticeably less dense on these sandy areas than the surrounding plains.

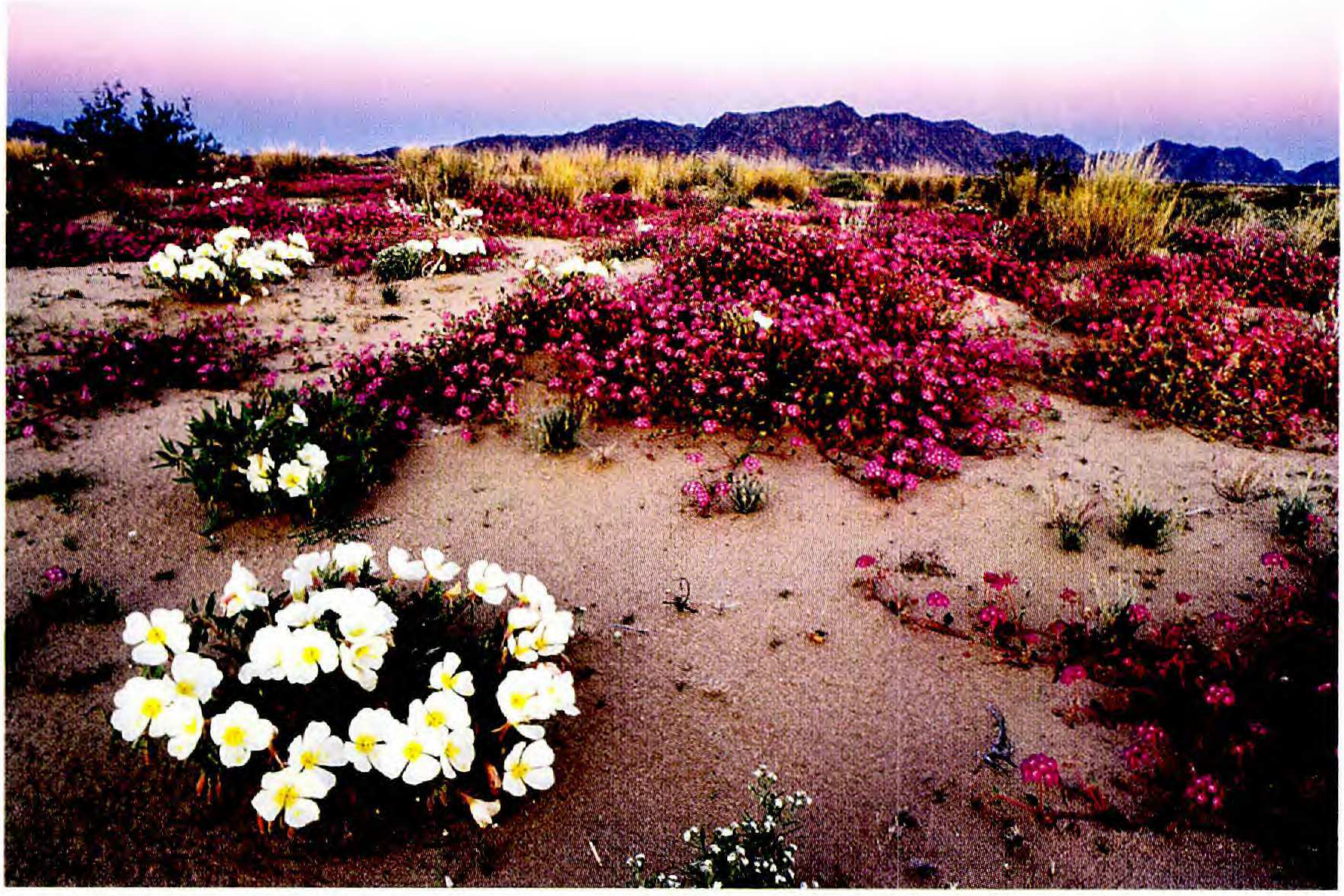

FIG. 3. Mohawk Dunes, during a "wet spring," 28 February 1998. *Oenothera deltoides* (white flowers) *Abronia villosa* (lavender-pink flowers), and *Pleuraphis rigida* (background). Looking eastward, Mohawk Mountains in background. Photo by Thomas R. Jones.

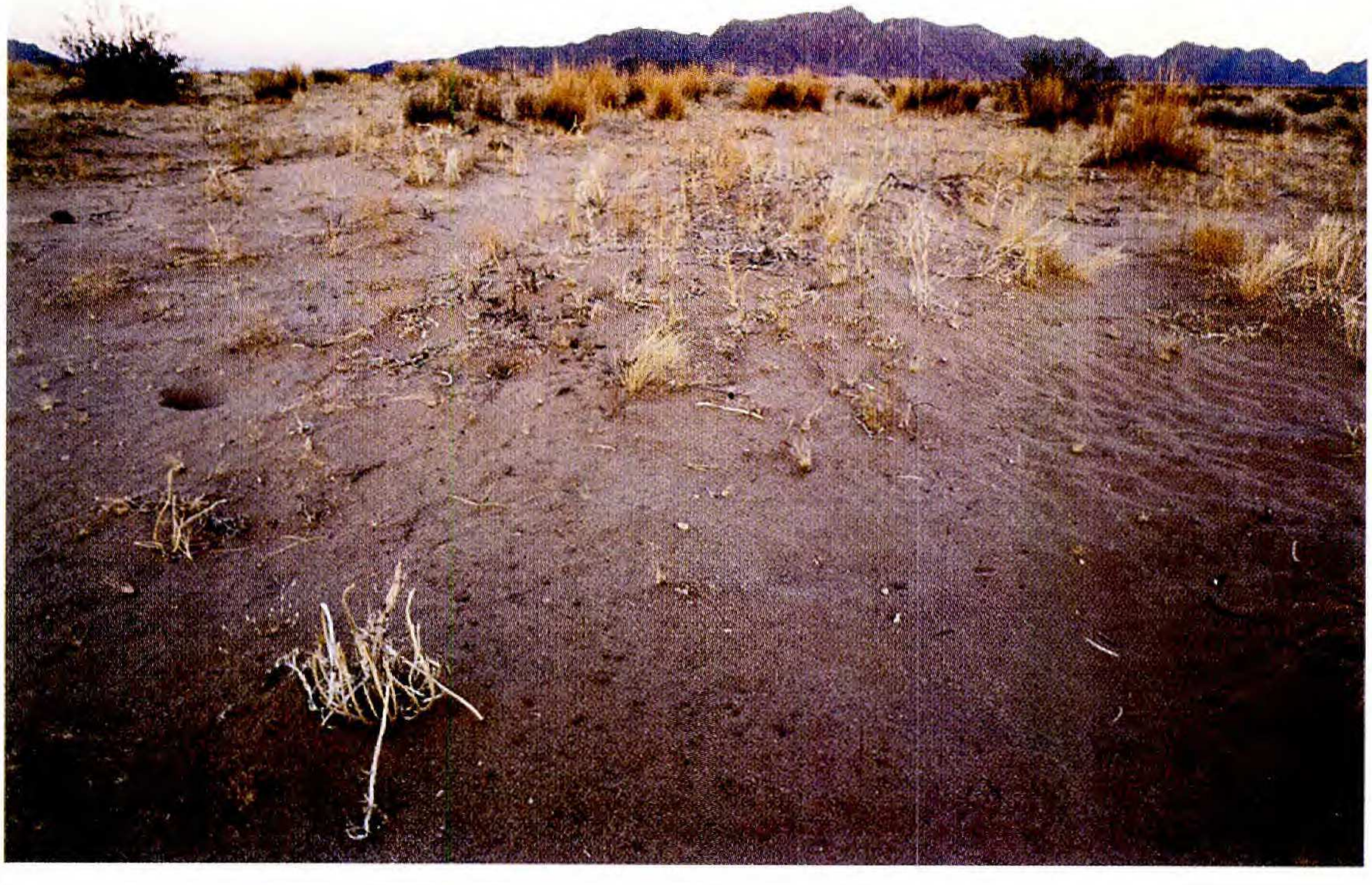

FIG. 4. Same view as Fig. 3, but during a drought year, 12 March 2002. The skeleton in foreground is the same *Oenothera deltoides* shown in Fig. 3 left foreground. Photo by Thomas R. Jones.

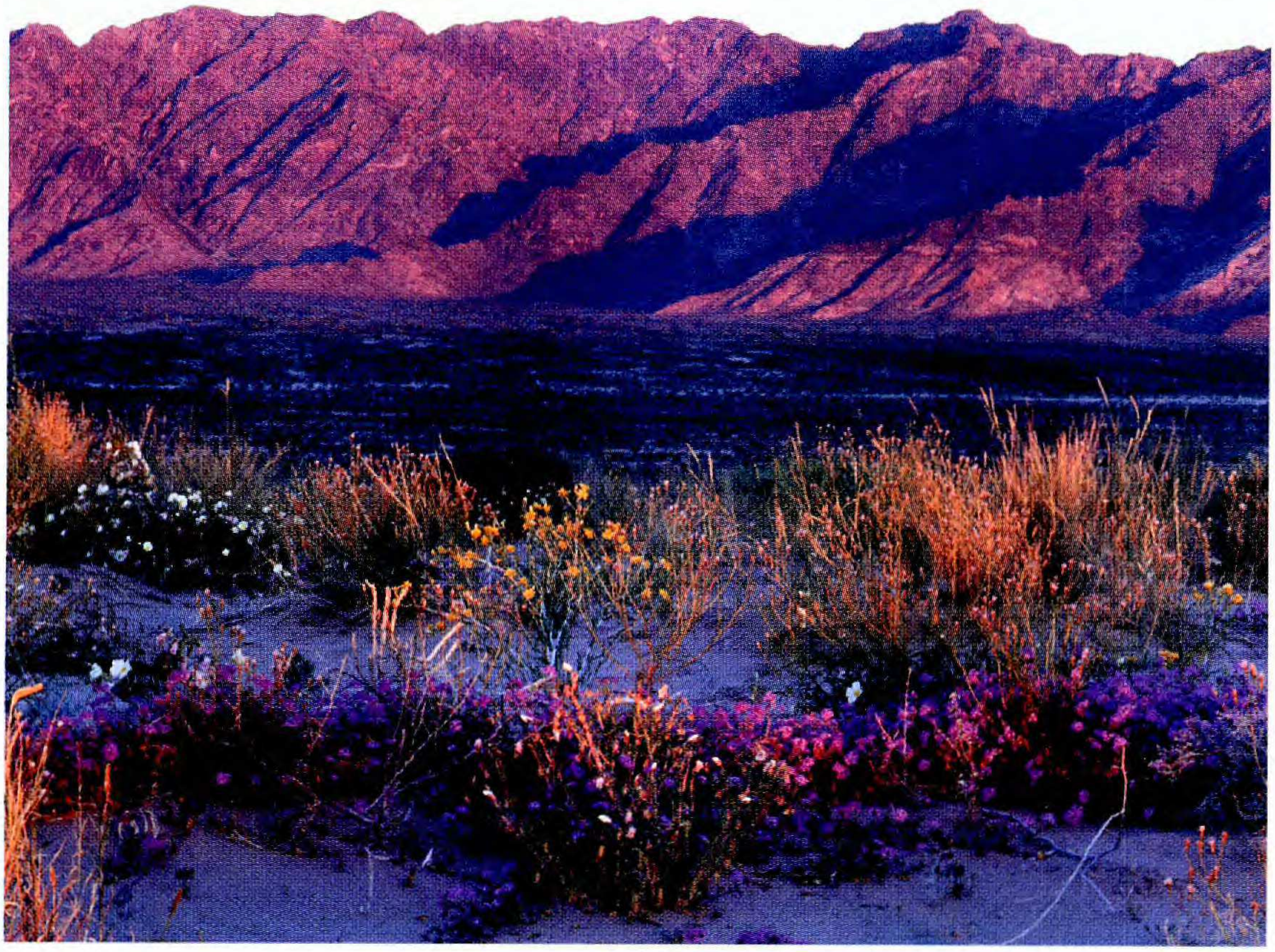

Fig. 5. Northern part of Mohawk Dunes looking eastward towards Mohawk Mountains, April 1998. *Abronia villosa* (forground) and *Mentzelia multiflora* (center forground). Photo by Charles Hedgcock.

Comparison to Other Dune Systems

In terms of plant diversity and species composition, the Mohawk Dunes, as expected, show the greatest affinity to other inland dune systems within the Sonoran Desert. Of these, the greatest similarity exists with dunes of the Gran Desierto, Sonora, the largest inland dune system in North America (5,000 km^2), centered approximately 70 km to the southwest of the Mohawk system (Felger 1980, 2000). The Pinta Sands of Cabeza Prieta National Wildlife Refuge, 38 km to the south are the closest dune system, but these dunes are only a northern extension of the Gran Desierto, being some 5 km from the northernmost dunes of that system. The Algodones dunes (709 km^2) of southeastern California, 90 km to the west, share many plants with the Mohawk system (*see* WESTEC Services 1977). Although no plant is endemic to the Mohawk Dune system alone, *Cryptantha ganderi*, *Dimorphocarpa pinnatifida*, and *Stephanomeria schottii* are endemic to dunes and adjacent sand flats of the Lower Colorado region of the Sonoran Desert.

The Mohawk system has among the highest species richness for its size among southwestern dunes. The enormous Gran Desierto dune system has a flora of only 85 species (Felger 2000), amazingly few species for such an immense area. The relatively low species richness probably can be attributed to the low habitat diversity, extreme aridity, and harsh conditions brought about by moving sand. The Mohawk Dunes, with less than 2% of the area, supports a dune flora of 78 species (Table 2). The Algodones Dunes are reported to support a flora of 97 species (Bowers 1984, interpreting WESTEC Services 1977; this number, however, cannot be considered wholly accurate based on the available data). The Kelso Dunes in the eastern Mohave Desert support 75 species (Thorne et al. 1981), with some overlap with Mohawk Dune species. It is interesting to note the similarity in species richness among these diverse dune systems.

Species composition of the dominant dune vegetation in the Mohawk Dunes is similar to that of other Sonoran Desert dune systems (Felger 2000; Warren & Laurenzi 1987). Five species typically comprise at least 90% of the perennial vegetative cover on these systems, with *Ambrosia dumosa* and *Pleuraphis rigida* the most abundant, and *Psorothamnus emoryi*, *Ephedra trifurca*, and *Tiquilia plicata* as common associates.

Absent from the Mohawk Dunes are several dune-endemic species which are relatively common in the Gran Desierto and/or Yuma Dunes and Algodones Dunes, including *Asclepias erosa*, *Croton wigginsii*, *Drymaria viscosa*, *Eriogonum deserticola*, *Euphorbia platysperma*, *Helianthus niveus*, *Heterotheca thiniicola*, *Pholisma sonorae*, *Larrea divaricata* var. *arenaria*, *Palafoxia arida* var. *gigantea*, and *Triteleiopsis palmeri* (e.g., Felger 1980, 2000; Felger et al. 1997). This may be due to the relative isolation of the Mohawk Dunes. *Eriastrum eremicum*, found on the Mohawk Dunes is not present at the other dune systems; it is more characteristic of Arizona Upland locales and has its southwestern limits near the Mohawk Dunes.

Non-native Species

Five non-natives species, all native to the Old World, are recorded in the flora: *Brassica tournefortii*, *Mollugo cerviana*, *Schismus arabicus*, *Sonchus asper*, and *Tamarix ramosissima*. *Tamarix* is no longer present, and the remaining four occur on the dunes and all but *Mollugo* are also found on the sand flats. The *Brassica*, *Mollugo*, and *Schismus* are common and well established, while *Sonchus asper* is widely scattered but not common. Additional invasive weedy species undoubtedly will arrive on the scene. A number of non-native, weedy plants are conspicuously absent from the Mohawk flora but are common in nearby, mostly disturbed areas, e.g., buffelgrass (*Pennisetum ciliare* (L.) Link) and tumbleweed (*Salsola tragus* L.).

A flora with only 4% non-native species is remarkable, since the average for the Sonoran Desert is about 11.6% (Felger 2000; Wilson et al. 2002). It is not, however, unusual for regional dune systems. The Mohawk Dunes and the enormous Gran Desierto dune system contain only the same four non-native species and the abundance patterns are likewise similar (see Felger 2000:21). The unusually low number of non-natives may be due to the uniqueness, isolation, and relatively undisturbed condition of the habitat.

Although competition between plants on dunes is reported to be negligible (Bowers 1982), *Brassica tournefortii* and *Schismus arabicus* certainly seem invasive and detrimental to native species (Felger 2000; Wilson et al. 2002). Their very rapid early growth seems to negatively affect native plants. On the Mohawk dunes as well as elsewhere in the Sonoran Desert (e.g., Felger 2000), *Brassica* rosette-leaves and *Schismus* plants spread over seedling and juvenile plants of the apparently slower-growing native ephemerals, possibly smothering or shading them out, or preventing their germination (Fig. 6).

ANNOTATED SPECIES ACCOUNTS

The flora is listed alphabetically by family, genus, and species. Accepted scientific names, including the variety (var.) or subspecies (subsp.), are in **bold**. Selected synonyms of scientific names are in *italics* within brackets [-]. Common names follow the scientific names, and when known are given in English and Spanish. Brief characterizations are provided for each species, including the usual flowering time and in most cases the general or most conspicuous color of the flower (flower color is often omitted for species with small, inconspicuous flowers). Growth and flowering, of course, is almost entirely linked to rainfall and soil moisture. During extended drought, such as 2001 and 2002, many plants fail to grow or flower. More detailed descriptions and distributional information can be found in many sources, e.g., Felger (1980, 2000), Hickman (1993), Kearney and Peebles (1960), Wiggins (1964), and the various contributions to the Vascular Plants of Arizona (Vascular Plants of Arizona Editorial Committee 2001).

The distributional information is based on field observations and for the most part verified with herbarium specimens primarily at the herbaria of the University of Arizona (ARIZ) and Arizona State University (ASU). Specimens cited are at ARIZ, unless otherwise indicated, and in many cases duplicates, especially those of Felger, are mostly at ASU, RSA, and SD. The five non-native species are indicated with an asterisk (*). The area had abundant spring rains during 1995 and 1998, and abundant summer rains during 1996 and 1997. In our opinion we likely encountered plants of nearly all of the ephemeral species present in the seed bank as well as all of the perennials.

AMARANTHACEAE - Amaranth Family

Amaranthus fimbriatus (Torr.) Benth. ex S. Watson. Fringed pigweed; *bledo, quelitillo*. Hot-weather annuals; flowers greenish and white. Sand flats and dunes. *Felger 97-63 et al.; Felger 96-138 & Turner.*

Amaranthus palmeri S.Watson. Carelessweed, pigweed; *bledo, quelite de las aguas*. Hot-weather annuals. Sand flats, especially near

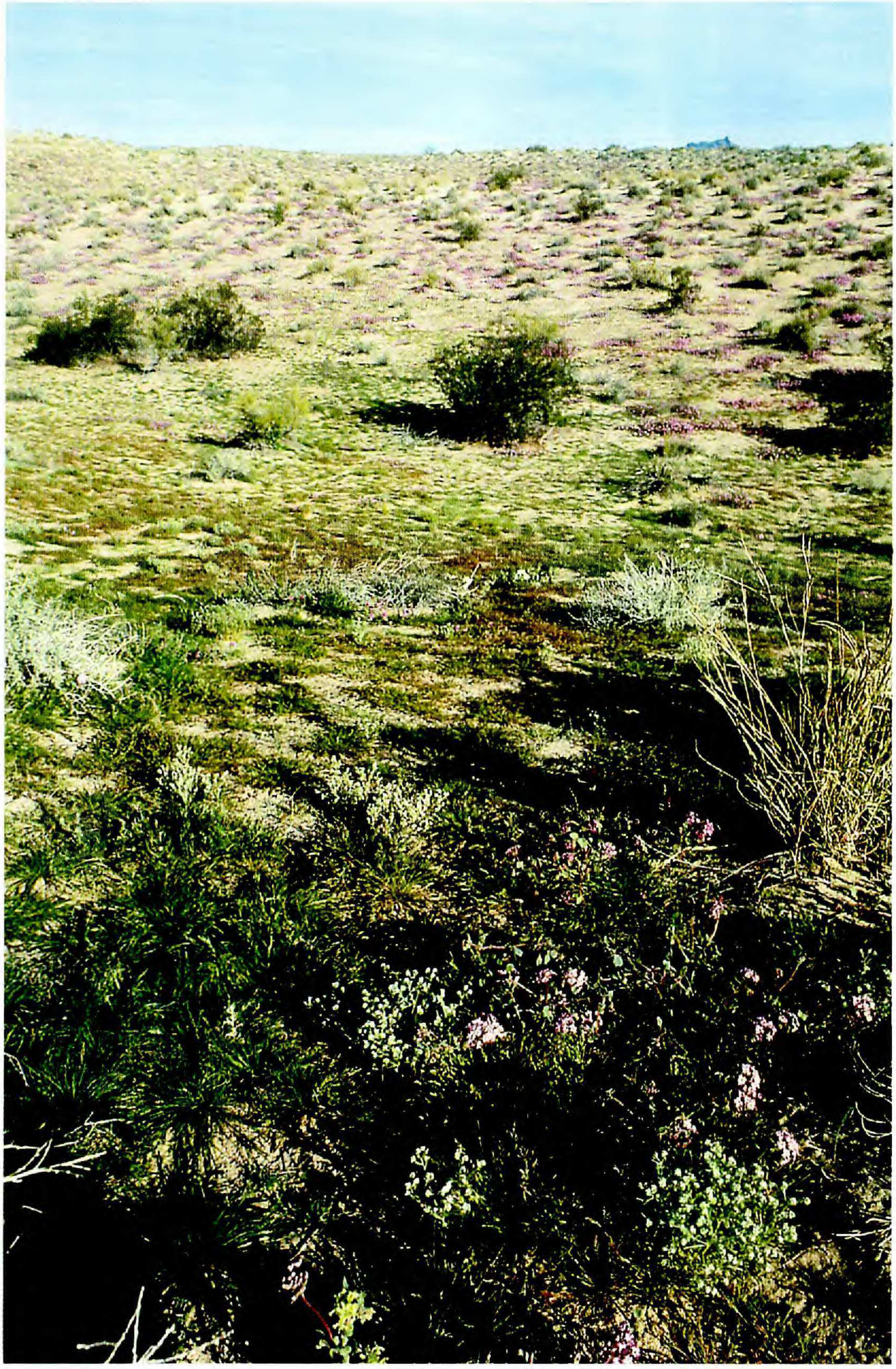

Fig. 6. Northeast side of Mohawk Dunes looking northwest. *Schismus* in left foreground, *Abronia* (lavender-pink flowers), *Pleuraphis* in right foreground, dune swale in mid-distance, and dune slope in background with *Larrea* and *Abronia*. April 1998. Photo by Charles Hedgcock.

the south end of the dune field. *Felger 97-79 et al.*

Tidestromia lanuginosa (Nutt.) Standl. subsp. **eliassoniana** Sanchez-del Pino & Flores Olvera. Honeysweet; *hierba ceniza, hierba lanuda.* Hot-weather annuals; flowers yellow. Widespread and common, sand flats and dunes. *Felger 97-71 et al.*; *Felger 96-149 & Turner.*

ASCLEPIADACEAE - Milkweed Family

Asclepias subulata Decne. Desert milkweed, reedstem milkweed; *jumete, mata candelilla.* Perennials with multiple, semi-succulent stems; flowering during warmer months; flowers waxy, cream- and yellow-white. Occasional in washes in sand flats near north side of dune field. *Turner s.n., 12 Nov 2001.*

Funastrum cynanchoides (Decne.) Schlt. var. **hartwegii** (Vail) Krings [*Sarcostemma cynanchoides* Decne. subsp. *hartwegii* (Vail) R.W. Holm; *Funastrum heterophyllum* (Engelm.) Standley]. Climbing milkweed; *güirote.* Perennial vines; flowering at various seasons; flowers maroon and white. Occasional in washes in sand flats near the northern part of the dunes. *Felger & Turner,* 24 Sep 1996, observation.

ASTERACEAE - Daisy or Composite Family

Ambrosia confertiflora DC. Slimleaf ragweed; *estafiate.* Herbaceous perennials; flowering late spring and in fall. Occasional in depressions in sand flats near the dunes. *Felger 97-77 et al.*

Ambrosia deltoidea (Torr.) W.W. Payne. Triangle-leaf bursage; *chamizo forrajero.* Small shrubs. Common on dunes, sand flats, and playa margins. Summer dormant. *Felger 96-169 & Turner; Reina-G. 96-213 & Van Devender.*

Ambrosia dumosa (A. Gray) W.W. Payne. White bursage; *chamizo.* Small shrubs; flowering September-April. Summer-dormant, new leaves and flowers may appear as early as September. Very common on sand flats and dunes including higher dunes. *Felger 97-66 et al.; Felger 96-127 & Turner; Reina-G. 96-215 & Van Devender.*

Baccharis salicifolia (Ruiz & Pav.) Pers. [*B. glutinosa* Pers.]. Seep willow; *batamote.* Leafy shrubs. About ten plants, mostly 2-2.5 m tall, along the southern edge of the playa apparently grew during the exceptionally wet year of 1992-1993, and perished by the end of 1994. *Felger 96-154 & Turner.*

Baccharis sarothroides A. Gray. Desertbroom; *escoba amargo, romerillo.* Broomlike shrub. One individual, ca. 2 m tall, at northeast margin of playa. *Felger 96-150 & Turner.*

Baileya pauciradiata Harv. & A. Gray ex A. Gray. Few-flowered desert marigold. Spring annuals; flowers yellow. Dunes and sand flats. *Reichenbacher 601; Salywon et al. 988* (ASU); *Turner 95-26.*

Baileya pleniradiata Harv. & A. Gray ex A. Gray. Woolly desert marigold; *tecomblate.* Annuals, mostly in spring, sometimes with summer rains; flowers yellow. Dunes and sand flats. *Felger 98-56 & Evans; Salywon et al. 987* (ASU); *Turner 95-25, 95-30.*

Chaenactis stevioides Hook. & Arn. Desert pincushion. Cool-season annuals; flowers white or cream, pink in bud. Dunes, especially lower dunes, and sometimes on sand flats. *Felger 98-58 & Evans; Goldberg 77-87; Turner 95-5.*

Dicoria canescens A. Gray subsp. **canescens**. Bugseed. Annuals; germinating at least with spring rains, their numbers variously reduced by late-spring and early summer drought, recorded fully leafed-out in August, and variously flowering from late October through December; plants often robust to 1 m tall and becoming tumbleweeds after seeds ripen. Seedlings and juvenile plants quickly produce a deep taproot and have narrow, elongated leaves, the older plants produce broad and shorter leaves. Restricted to dunes, especially moving sands of higher dunes. On 24 November 1994, Turner observed plants in full bloom, abuzz with honeybees but no native bees; the honeybees probably were gathering pollen since the plants are presumably wind-pollinated. On 23 June 1995, Turner found clipped stems and leaves scattered around stripped stems—evidence of herbivory by kangaroo rats (*Dipodomys* sp.). *Felger 98-59 & Evans; Reichenbacher s.n., 7 Mar 1980; Turner 94-2.*

Eriophyllum lanosum (A. Gray) A. Gray. Woolly daisy. Small, cool-season annuals; disk flowers yellow, rays white. Sand flats. *Felger 98-91 & Evans.*

Filago arizonica A. Gray. [*Logfia arizonica* (A. Gray) Holub]. Arizona fluffweed. Small, cool-season annuals. Low areas in sand flats. *Felger 98-93 & Evans.*

Geraea canescens Torr. & A. Gray. Desert sunflower, desert gold. Coarse spring annuals; flower heads sunflower-like, bright yellow. Dunes and sand flats. *Goldberg 77-89; Turner 95-27.*

Isocoma acradenia (Greene) Greene var. **acradenia** [*Haplopappus acradenius* (Greene) S.F. Blake]. Alkali goldenbush. Small shrubs; flowering various seasons, at least in spring and fall; flowers yellow. Occasional and localized at the playa margin and sand flats at roadsides. *Felger 96-143 & Turner, 96-155; Reina-G. 96-214 & Van Devender.*

Malacothrix glabrata (A. Gray ex D.C. Eaton) A. Gray [*M. californica* DC. var. *glabrata* A. Gray ex D.C. Eaton] Smooth desert-dandelion. Spring annuals; flower heads white with a pale yellow center. Dune slopes and higher dunes, scattered to sometimes seasonally common. *Felger 98-60 & Evans; Reichenbacher 603; Turner 95-6.*

Monoptilon bellioides (A. Gray) H.M. Hall. Desert star. Small, spring annuals; rays white, turning pale lavender with age, the disk yellow. Sand flats and sometimes on lower dunes; occasional at playa margin. *Felger 98-61 & Evans, 98-96; Turner 95-21.*

Palafoxia arida B.L. Turner & M.I. Morris var. **arida**. Spanish needles. Non-seasonal annuals; flowers white to pink with purple anthers. Sand flats and dunes at all elevations. Some of the larger, robust plants on the dunes approach var. *gigantea* (M.E. Jones) B.L. Turner & M.I. Morris in having larger flower heads and achenes. *Felger 98-4 et al.; Felger 96-139 & Turner; Turner 95-4.*

Pectis papposa Harv. & A. Gray var. **papposa**. Desert chinchweed; *manzanilla del coyote*. Hot-weather annuals; herbage pungently aromatic; flowers bright yellow. Sand flats and dunes. Highly variable in size, drought-stressed plants can mature with a single flower head. *Felger 97-56 et al., 97-72; Felger 96-134 & Turner.*

Rafinesquia neomexicana A. Gray. Desert chicory. Spring annuals; flowers white. Dunes, especially dune slopes and swales, also lower dunes and sand flats; mostly growing through small shrubs such as *Ambrosia dumosa*. *Felger 98-85 & Evans; Felger 98-12 et al.*

*__Sonchus asper__ (L.) Hill subsp. **asper**. Spiny sowthistle; *chinita*. Winter-spring annuals; flowers pale yellow. Occasional and widely scattered in natural areas such as small arroyos and depression on sand flats, dune swales, lower dunes, and rarely on higher dunes. *Felger 98-62 & Evans, 98-95.*

Stephanomeria schottii (A. Gray) A. Gray. Schott's wire-lettuce. **Fig. 7.** Late spring annuals; flowers white tinged with violet. Seasonally abundant and widespread on dunes at all elevations and also low stabilized dunes of the nearby San Cristobal Valley. *Burgess 5067; Felger 98-16 et al.; Felger 98-63 & Evans; Reichenbacher 596; Turner 95-14.* San Cristobal Valley dunes, *Anderson 98-40, 98-54* (ASU).

Endemic to dunes and sand flats in the Gran Desierto in northwestern Sonora and southwestern Arizona in Yuma County (Felger 2000, Lehto 1979). This species has a Global Heritage Status Rank of G2 (imperiled globally).

Stylocline micropoides A. Gray. Desert neststraw. Small, spring annuals. Locally and seasonally common in swales and depressions among dunes, and sometimes on surrounding sand flats. *Felger 98-83 & Evans.*

BORAGINACEAE - Borage Family

Amsinckia tessellata A. Gray. Checker fiddleneck. Cool-season annuals; flowers yellow. Common on dunes and sand flats. *Turner 95-13.*

Cryptantha angustifolia (Torr.) Greene. Narrowleaf cryptantha, desert cryptantha. Cool-season annuals; corollas white with a yellow throat. Widespread across the dunes and sand flats; one of the most common and ubiquitous spring annuals in the region. *Turner 95-12.*

Cryptantha ganderi I.M. Johnst. Cool-season annual, sometimes locally common; flowers minute, white; fruits with 2 smooth nutlets.

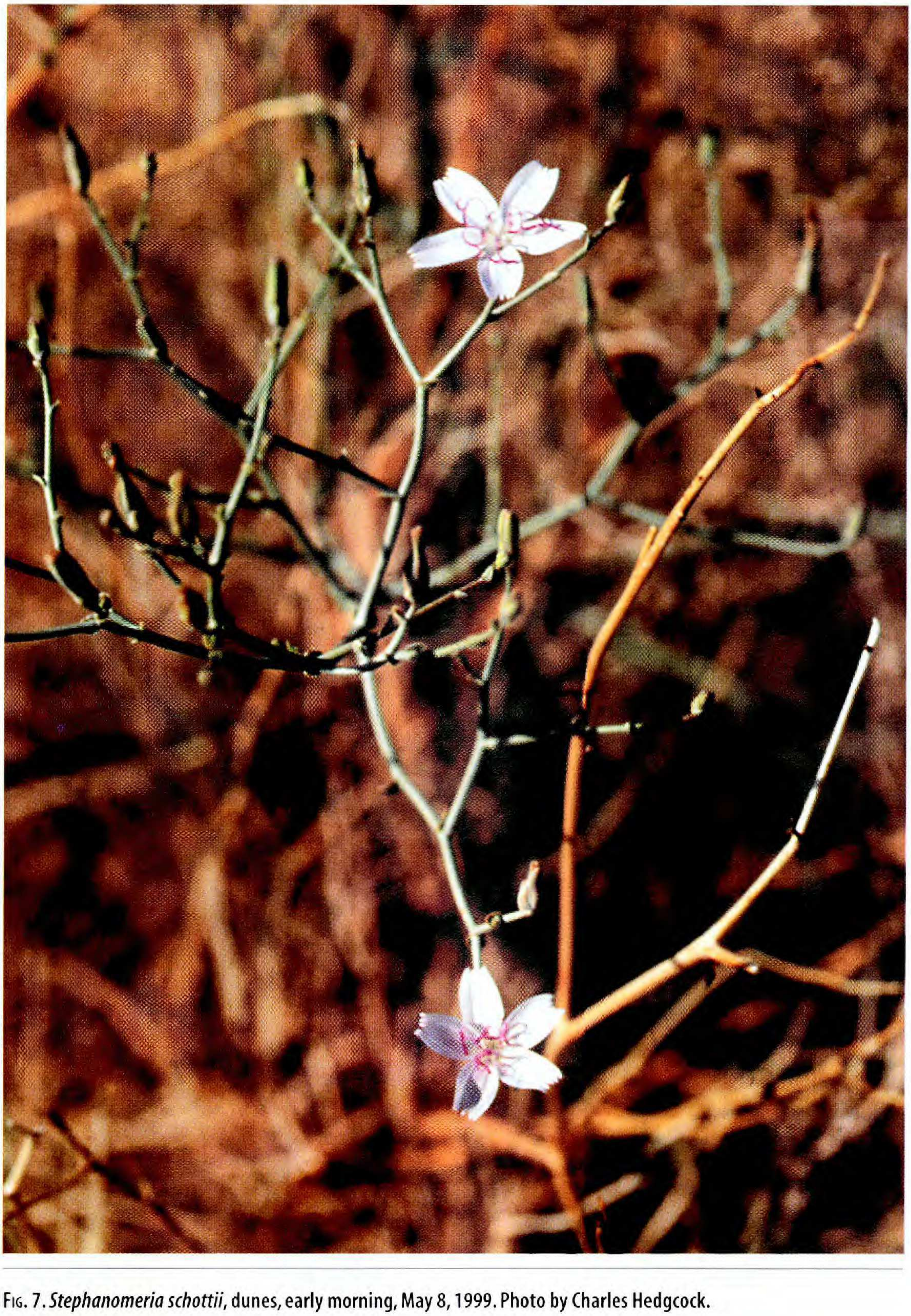

FIG. 7. *Stephanomeria schottii*, dunes, early morning, May 8, 1999. Photo by Charles Hedgcock.

Lower dunes and steep dune slopes; often beneath shrubs such as *Ephedra*. *Felger 98-64 & Evans.*

Dunes and sand flats of the Gran Desierto in northwestern Sonora, and extending into adjacent southwestern Arizona on the Pinta Sands in Cabeza Prieta National Wildlife Refuge, and disjunct on the Mohawk Dunes, and similar habitats in southeastern California and Baja California. First confirmed for Arizona in 1993 (Felger 2000; Felger et al. 1993). This species has a Global Heritage Status Rank of G2 (imperiled globally).

Cryptantha maritima (Greene) Greene [includes var. *maritima* and var. *pilosa* I.M. Johnst.]. White-haired cryptantha. Cool-season annuals; corollas white. Widely scattered on sand flats. *Felger 98-99 & Evans.*

Cryptantha micrantha (Torr.) I.M. Johnst. subsp. **micrantha**. Dwarf cryptantha. Cool-season annuals; flowers minute, white. Widespread on dunes at all elevations. *Felger 96-164 & Turner.*

Heliotropium convolvulaceum (Nutt.) A. Gray var. **californicum** (Greene) I.M. Johnst. Morning-glory heliotrope. Non-seasonal annuals, mostly germinating and growing during warm weather with sufficient soil moisture; flowers white and showy. Seasonally scattered on dunes. *Van Devender 92-644.*

Heliotropium curassavicum L. [The plants are var. *oculatum* (A. Heller) I.M. Johnst. ex Tidestr., but the variety is probably not worthy of recognition, see Felger 2000]. Alkali heliotrope; *hierba del sapo*. Semi-succulent perennial herbs or facultative annuals; herbage frost-sensitive; corollas white, the center yellow and turning purplish with age. Widespread across the playa, sometimes locally abundant. *Felger 96-152 & Turner; Reina-G. 96-211 & Van Devender; Turner 94-1.*

Pectocarya heterocarpa (I.M. Johnst.) I.M. Johnst. Mixednut comb-bur. Cool-season annuals; corollas white with a yellow center. Widespread and common, dunes and sand flats. *Felger 98-65 & Evans.*

Pectocarya platycarpa (Munz & I.M. Johnst.) Munz & I.M. Johnst. Broadwing comb-bur. Cool-season annuals; flowers white. Dunes and sand flats. *Felger 98-90A & Evans.*

Tiquilia plicata (Torr.) A.T. Richardson. Fanleaf crinklemat. Perennial herbs from deep, thick and black roots; flowering spring and summer; corollas lavender. Mostly on moving dunes, occasional on low sand hills on sand flats. *Felger 97-70 et al.; Felger 96-136 & Turner; Reichenbacher 599.*

BRASSICACEAE (CRUCIFERAE) - Mustard Family

***Brassica tournefortii** Gouan. Sahara mustard, wild turnip; *mostaza*. Cool-season annuals; plants highly variable in size; flowers pale yellow and apparently selfing (Felger 2000). Widespread and especially abundant on dunes during years of high winter-spring rains; sand flats and dunes including highest dunes. Larger plants with basal rosette leaves each to 72 cm long, these leaves spreading close to ground and often covering other spring annuals. The leaves are bitter-tasting except those of very small, young plants. *Felger 98-2 et al.; Turner 95-10.*

Caulanthus lasiophyllus (Hook. & Arn.) Payson. Cool-season annuals; flowers minute, white to pinkish. Mostly in swales and on north-facing dune slopes, locally common; also sand flats in washes and swales, mostly at the base of shrubs. *Felger 98-67 & Evans.*

Dimorphocarpa pinnatifida Rollins [*Dithyrea wislizenii* Engelm., in part]. Dune spectaclepod. **Fig. 8.** Cool-season annuals, sometimes more than 1 m across; flowers white and fragrant. Dunes, especially the higher dune crests. Endemic to dunes and sand flats in Yuma County and the Gran Desierto in northwestern Sonora. *Felger 98-6 et al.; Salywon et al. 985; Turner 95-7.* San Cristobal Valley dunes, *Anderson 98-37* (ASU).

Dithyrea californica Harv. Spectaclepod. Cool-season annuals; flowers cream-colored, highly fragrant. Widespread across the dunes, especially lower dunes and slopes. *Felger 98-5 et al.; Salywon et al. 984* (ASU).

Lepidium lasiocarpum Nutt. ex Torr. & A. Gray. Sand peppergrass. Cool-season annuals; herbage peppery-tasting; flowers minute, white. Widespread, mostly on lower dunes and swales, and expected on sand flats. *Felger 98-3 et al.*

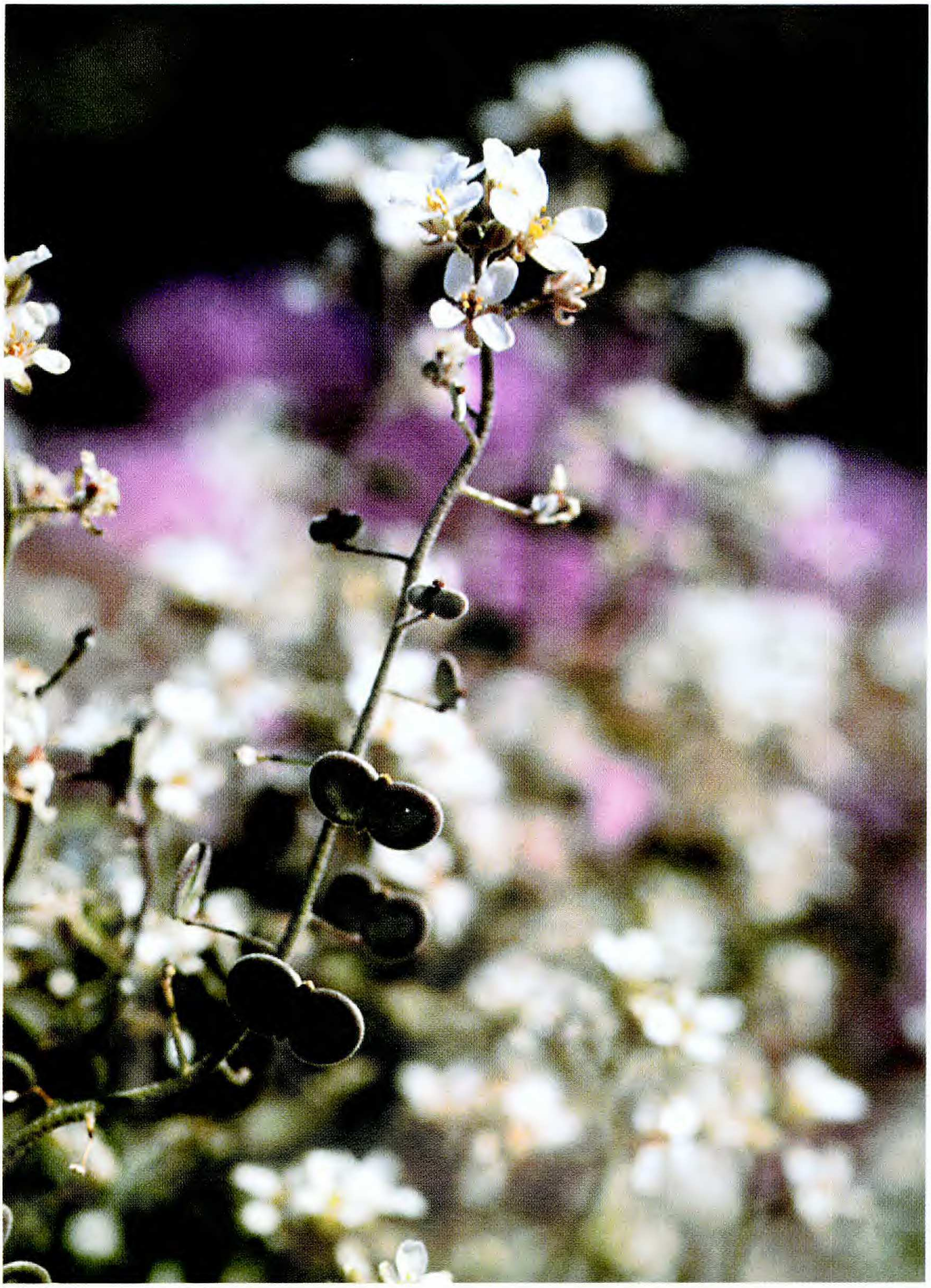

FIG. 8. *Dimorphotheca pinnatifida*, dunes, April 1998. Photo by Charles Hedgcock.

Physaria tenella (A. Nels.) O'Kane & Al-Shehbaz [*Lesquerella tenella* A. Nels.]. Desert bladderpod. Cool-season annuals; flowers bright yellow. Sand flats, often growing through bursage (*Ambrosia* spp.). *Felger 98-17 et al.*; *Felger 98-98 & Evans*.

Streptanthella longirostris (S. Watson) Rydb. Longbeak twistflower. Cool-season annuals; herbage often glaucous and sometimes semisucculent; flowers minute, pale yellowish-white. Widely scattered across dunes, especially swales and north-facing slopes, and less common on higher dunes; also sand flats, especially at the base of shrubs. *Felger 98-66 & Evans*; *Felger 98-7 et al.*; *Salywon et al. 983* (ASU).

CACTACEAE - Cactus Family

Carnegiea gigantea (Engelm.) Britton & Rose. Saguaro. Columnar cactus; one individual ca. 6 m tall with two large branches. Early summer. Sand flat on east side of dunes.

Cylindropuntia echinocarpa (Engelm. & J.M. Bigelow) F.M. Knuth [*Opuntia echinocarpa* Engelm. & J.M. Bigelow; *O. wigginsii* L.D. Benson]. Silver cholla. Small chollas to 1+ m tall; April; flowers silvery white with green filaments. Mostly lower dunes and swales, especially with harder soils, and sand flats, widely scattered, mostly in small colonies. *Felger & Turner*, 24 Sep 1996, observation.

Echinocactus polycephalus Engelm. & J.M. Bigelow var. **polycephalus**. Many-headed barrel cactus. Multiple-headed, mound-forming barrel cactus; July; flowers yellow. One mature plant (14 living stems) on creosotebush flat near west side of dunes. *Turner*, 27 Jul 1995, photo.

Ferocactus wislizeni (Engelm.) Britton & Rose. Barrel cactus; *biznaga*. Unbranched barrel cactus to ca. 1.5 m tall; flowers orange to red-orange, at least August and September; fruits yellow and fleshy, ripe in late summer and early fall. Occasional and widely scattered on sand flats, especially west side of dunes, and rare on dunes. *Felger 97-52 et al.*; *Felger 96-165 & Turner, 96-171*.

Grusonia kunzei (Rose) Pinkava [*Opuntia kunzei* Rose. *O. stanleyi* Engelm. ex B.D. Jackson var. *kunzei* (Rose) L.D. Benson]. Desert club cholla. Large club cholla; flowers yellow, summer. One colony, mostly senescent, on low sand hummock on sand flat near southeast margin of dune field. *Felger & Turner*, 25 Sep 1996, observation.

CARYOPHYLLACEAE - Pink Family

Achyronychia cooperi Torr. & A. Gray. Sandmat, frostmat. Cool-season annuals; flowers papery white like the stipules. Dunes, especially lower dunes and also on highest dunes and sand flats. *Felger 98-68 & Evans*; *Salywon et al. 991* (ASU).

CONVOLVULACEAE – Morning-Glory Family

Cuscuta umbellata Kunth. Desert dodder. Warm-season annuals, stems twining; flowers white; parasitic on *Boerhavia* spp. Occasional; dunes and sand flats. *Felger 97-59 et al.*

EPHEDRACEAE - Ephedra Family

Ephedra trifurca Torr. ex S. Watson. Longleaf jointfir, Mormon tea; *canutillo*, *tepopote*. Robust, spreading shrubs to ca. 1.5 m tall, the trunks and major limbs thick and heavy. Twigs with 3 elongated scale leaves at each node. Dunes and sand flats. Pollen cones mature in March; seeds later in spring. *Felger 98-52 & Evans*; *Reina-G. 96-208 & Van Devender*; *Salywon et al. 986* (ASU).

EUPHORBIACEAE - Spurge Family

Ditaxis serrata (Torr.) A. Heller var. **serrata** [*Argythamnia serrata* (Torr.) Müll. Arg.]. Nonseasonal annuals; flowers inconspicuous, green and white. Dunes and sand flats. *Felger 97-51 et al., 98-21b*; *Felger 96-135 & Turner*.

Euphorbia abramsiana L.C. Wheeler [*Chamaesyce abramsiana* (L.C. Wheeler) Koutnik]. *Golondrina*. Hot-weather annuals; petal-like appendages absent or minute. Sand flats and dunes. *Felger et al. 97-57, 97-78 et al.*; *Felger 96-128 & Turner*.

Euphorbia polycarpa Benth. [*Chamaesyce polycarpa* (Benth.) Millsp.; *E. polycarpa* var. *hirtella* Boiss.]. Desert spurge; *golondrina*. Non-seasonal annuals, but most common during spring; petal-like appendages white, sometimes reduced or absent. Sand flats and dunes. *Felger 97-53 et al., 97-69; Felger 96-130 & Turner, 96-144.*

FABACEAE (LEGUMINOSAE) - Legume Family

Astragalus insularis Kellogg var. **harwoodii** Munz & McBurney ex Munz. Sand locoweed. Cool-season annuals; flowers rose-lavender and white. Dunes, especially lower dunes, and sand flats. *Felger 98-70 & Evans; Turner 95-24.*

Astragalus nuttallianus DC. var. **imperfectus** (Rydb.) Barneby. Smallflowered milkvetch. Cool-season annuals; flowers blue and white. Widely scattered; dunes, mostly swales and lower dunes, and sand flats. *Felger 98-74 & Evans; Felger 98-1 et al.*

Dalea mollis Benth. Silky dalea. Non-seasonal annuals. Dunes, especially lower dunes and dune slopes, and sand flats. *Felger 98-80 & Evans; Reichenbacher 437; Turner 95-27.*

Hoffmannseggia glauca (Ortega) Eifert [*Caesalpinia glauca* (Ortega) Kuntze]. Hog potato; *camote de ratón*. **Fig. 9.** Perennial herbs from deep-seated tuberous roots; flowering non-seasonally with warm weather and sufficient soil moisture; flowers yellow. Common across the playa. *Felger 98-50 & Evans; Reina-G. 96-212 & Van Devender; Turner 95-23.*

Lupinus arizonicus (S. Watson) S. Watson [*L. arizonicus* subsp. *sonorensis* J.A. Christian & D.B. Dunn] Arizona lupine; *lupino*. Cool-season annuals, flowers lavender-pink. Widespread and common, lower to higher dunes, slopes, and dune swales, and sand flats. Plants often ravaged by caterpillars of the painted lady butterfly (*Vanessa cardui*) and the white-lined sphinx moth (*Hyles lineata*; **Fig. 10**). *Felger 98-79 & Evans; Salywon et al. 993* (ASU); *Turner 95-3.*

Marina parryi (Torr. & A. Gray ex A. Gray) Barneby [*Dalea parryi* Torr. & A. Gray ex A. Gray]. Non-seasonal annuals (sometimes short-lived herbaceous perennials elsewhere); flowers dark blue. Dunes and expected on sand flats. *Reichenbacher*, 7 Mar 1980, observation.

Olneya tesota A. Gray. Ironwood; *palo fiero*. Trees ca. 6+ m tall; late April and May; flowers lavender-pink. Washes in sand flats near the northeast and southeast parts of dune field. *Felger & Turner*, 25 Sep 1996, observation.

Parkinsonia florida (Benth. ex A. Gray) S. Watson [*Cercidium floridum* Benth. ex A. Gray]. Blue palo verde; *palo verde*. Trees, ca. 5+ m tall; April, flowers bright yellow. Large wash in sand flats near north end of dune field. *Turner s.n., 12 Nov 2001.*

Parkinsonia microphylla Torr. [*Cercidium microphyllum* (Torr.) Rose & I.M. Johnst.]. Littleleaf palo verde; *palo verde*. Small trees; April and May; flowers pale yellow with a white banner. Scattered along washes in sand flats ca. 1-2 km from northeast and southwest margins of the dune field. *Felger & Turner*, 24 Sep 1996, observation.

Prosopis glandulosa Torr. var. **torreyana** (L.D. Benson) M.C. Johnst. Western honey-mesquite; *mezquite*. Large shrubs to small trees; flowering April and often sporadically through the summer and fall; flowers yellow. Playa margins and washes in sand flats in the surrounding desert, and rarely on dunes including dune swales and crests. Mesquites in the region are intermediate with *P. velutina* Wooton; most leaves have one pair of pinnae, as in *P. glandulosa*, although occasional leaves have two pairs as in *P. velutina*, and the herbage is often moderately pubescent as in *P. velutina* (see Felger 2000). *Felger 96-165 & Turner; Reina-G. 96-207 & Van Devender.*

Psorothamnus emoryi (A. Gray) Rydb. var. **emoryi** [*Dalea emoryi* A. Gray]. Emory indigobush. Shrubs to ca. 1 m tall; flowering after rains, spring and summer; flowers purple and white. Very common on dunes at all elevations and to margins of sand flats. *Felger 96-141 & Turner, 96-163; Felger 97-65 et al.; Reina-G. 96-209 & Van Devender.*

FOUQUIERIACEAE - Ocotillo Family

Fouquieria splendens Engelm. subsp. **splendens**. Ocotillo. Shrubs; spring; flowers red-orange. Common on sand flats at northeast margin of dune field. *Felger & Turner*, 24 Sep 1996, observation.

GERANIACEAE - Geranium Family

Erodium texanum A. Gray. False filaree, desert stork-bill. Cool-season annuals; flowers pink-purple. Sand flats. *Felger 98-18 et al.*

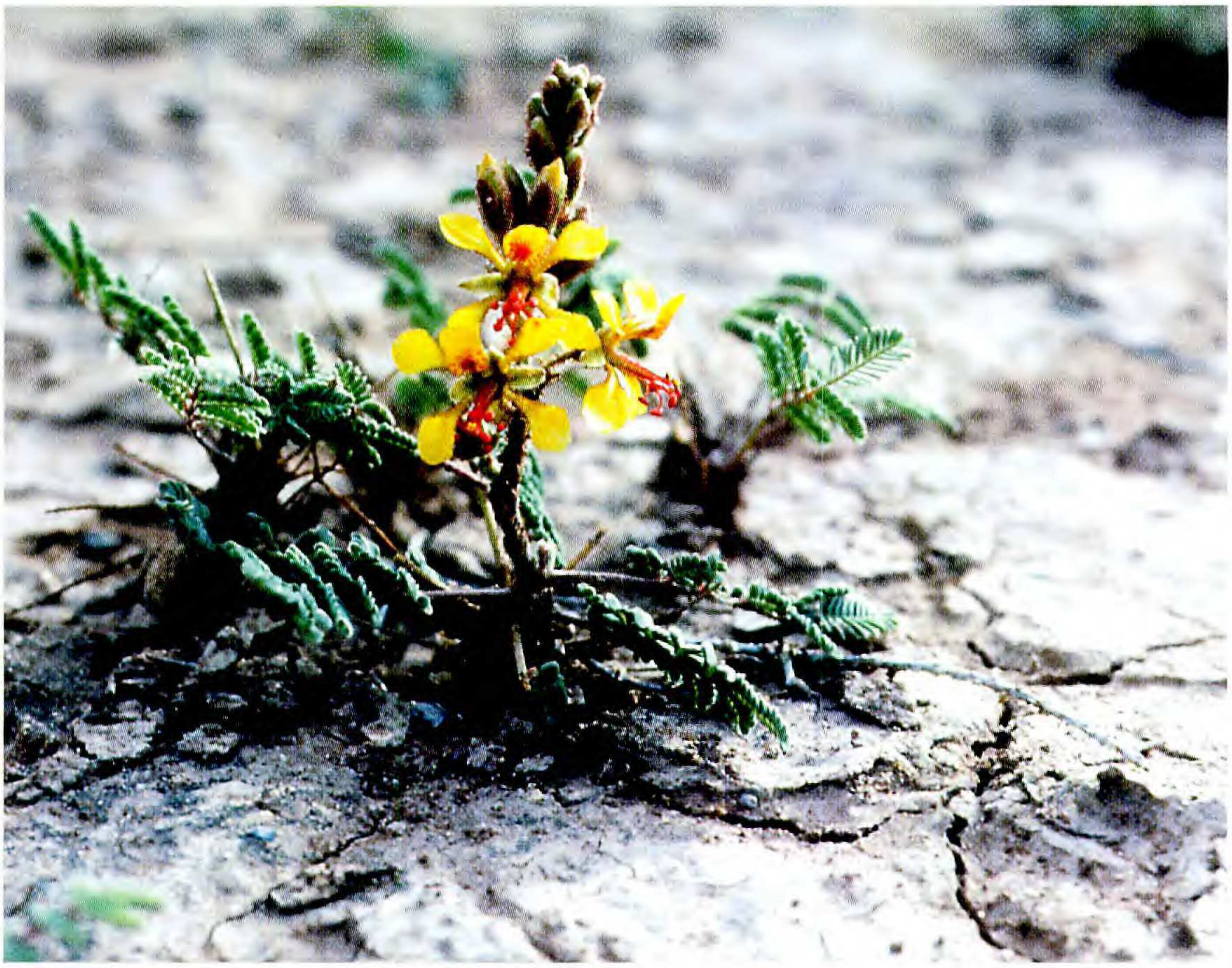

FIG. 9. *Hoffmannseggia glauca*, on the playa, June 1994. Photo by Charles Hedgcock.

HYDROPHYLLACEAE - Waterleaf Family

Nama hispidum A. Gray. Bristly nama. **Fig. 11.** Cool-season annuals; flowers lavender. Dunes and swales, playa margins, and sand flats. *Felger 98-71 & Evans*; *Turner 95-16.*

Phacelia ambigua M.E. Jones [*P. crenulata* Torr. ex S. Watson; *P. crenulata* var. *ambigua* (M.E. Jones) J.F. Macbr.]. Desert heliotrope. Cool-season annuals; flowers lavender-purple. Sand flats. *Felger 98-89 & Evans; Turner 95-9.*

KRAMERIACEAE - Ratany Family

Krameria erecta Willd. ex Schult. [*K. parvifolia* Benth.]. Range ratany. Dwarf shrubs; flowering at least spring and late summer; flowers bright magenta-purple. Widespread on sand flats. *Felger 96-148 & Turner, 96-172.*

Krameria grayi Rose & Painter. White ratany; *cósahui*. Shrubs; flowering various seasons; flowers magenta-purple. Sand flats; apparently rare or at least uncommon in the Mohawk Dune region although common in nearby areas. *Felger 96-147 & Turner.*

LILIACEAE (sensu lato) - Lily Family

Hesperocallis undulata A. Gray. Ajo lily, desert lily; *ajo silvestre*. **Fig. 12.** Perennials from a large, single bulb; flowering stalks sometimes reaching 1.5 m in height; February-April (early May); flowers white, 6-8 cm wide when fully open, opening late afternoon, closing with daytime heat of the next morning. Widespread, dunes and sand flats; best developed on dunes including highest dunes. *Felger 98-72 & Evans.*

LOASACEAE - Stick-Leaf Family

Mentzelia albicaulis Douglas ex Hook. White-stem blazingstar. Cool-season annuals; flowers small with uniformly bright-yellow petals. Dunes and especially in swales. *Felger 98-82 & Evans.*

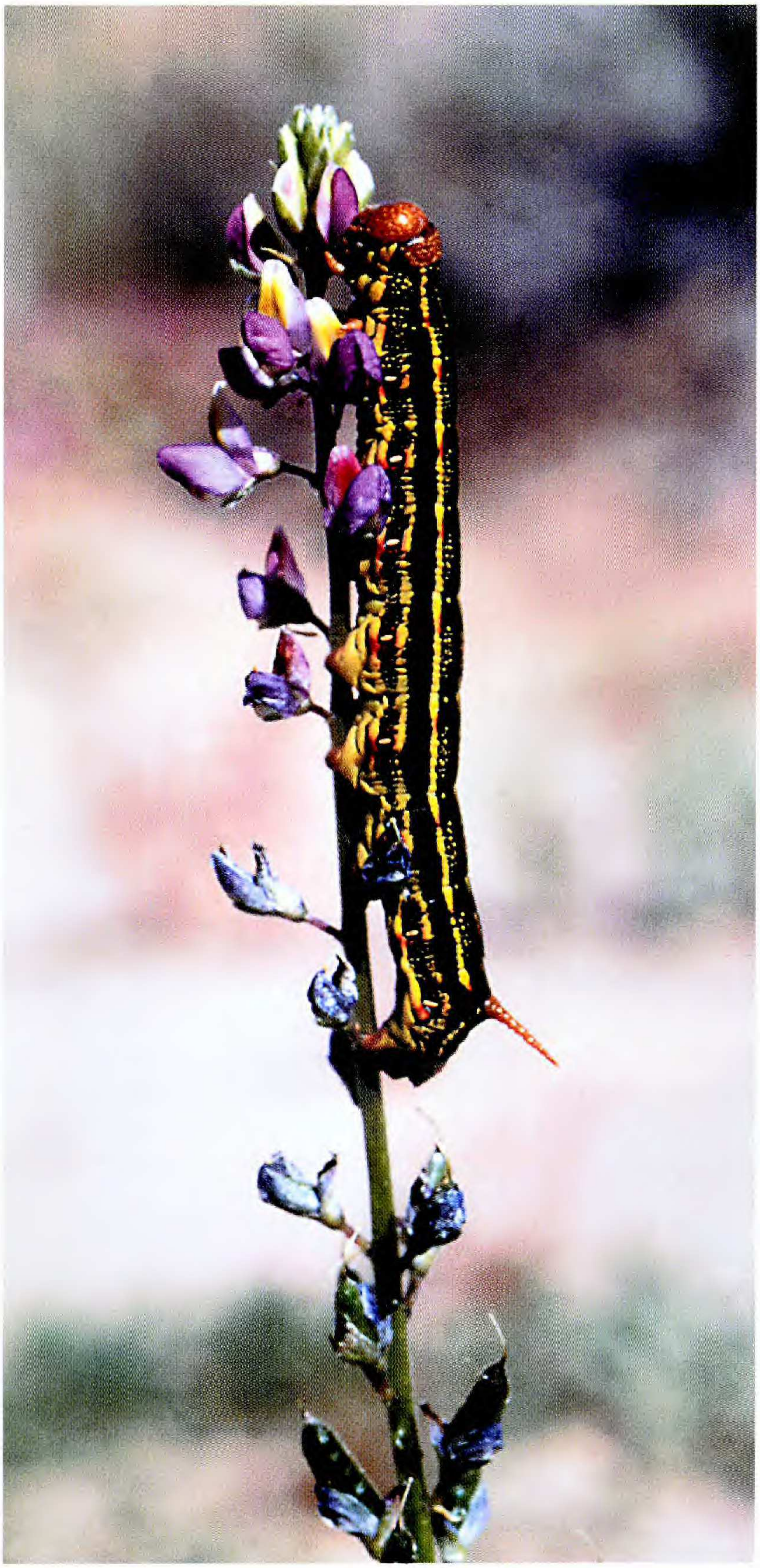

Fig. 10. *Hyles lineata* eating *Lupinus arizonicus*, April 1998. Photo by Charles Hedgcock.

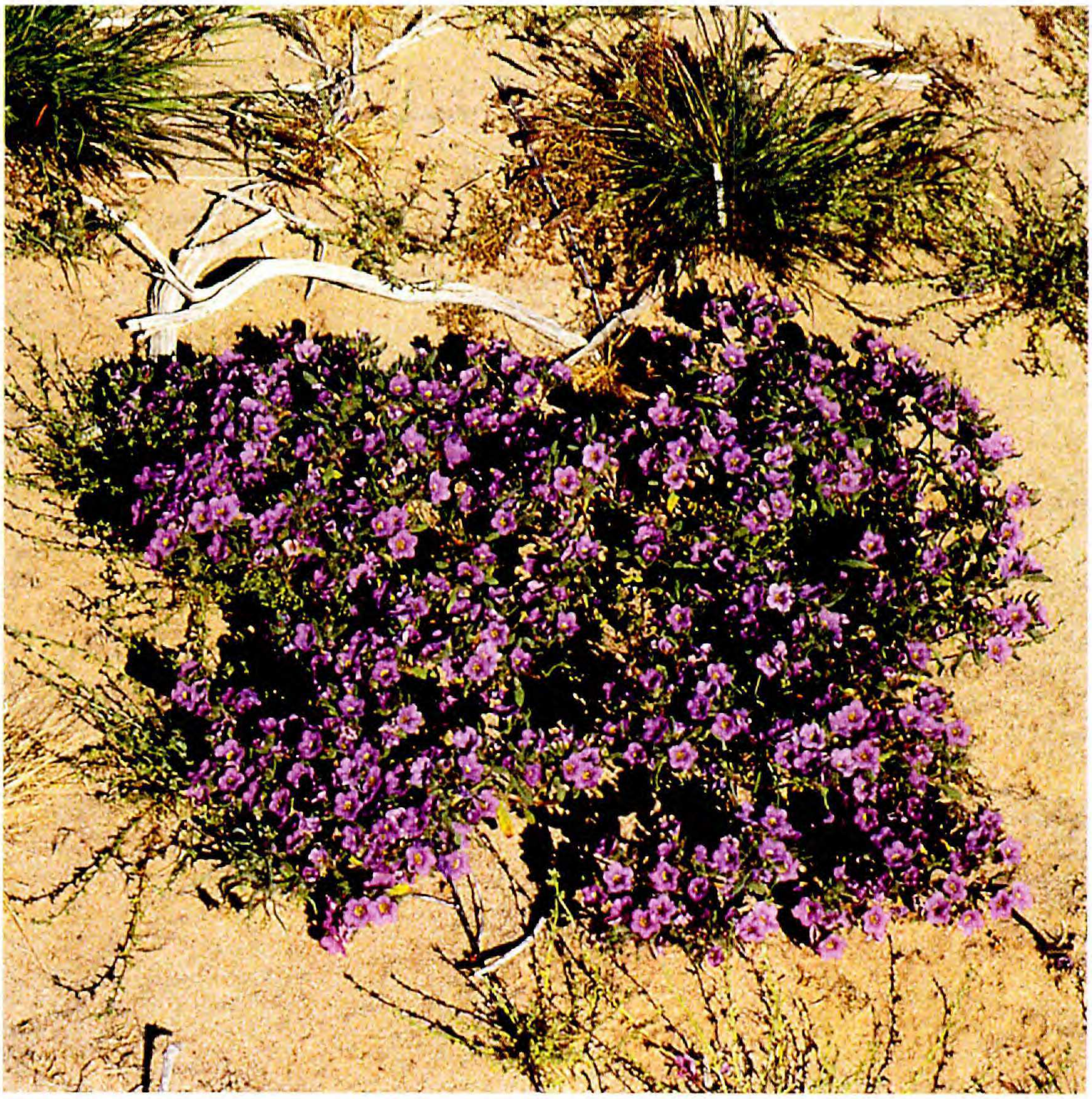

FIG. 11. *Nama hispidum* with *Schismus* above and *Pectocarya heterocarpa* below, April 1998. Photo by Charles Hedgcock.

Mentzelia multiflora (Nutt.) A. Gray. Blazingstar. Robust, cool-season annuals; flowers moderately large, yellow. Dunes and sometimes on sand flats. *Salywon & Shohet 558* (ASU); *Turner 92-2, 95-5.*

MALVACEAE - Mallow Family

Malvella sagittifolia (A. Gray) Fryxell [*Sida lepidota* A. Gray var. *sagittifolia* A. Gray]. Narrowleaf mallow. Perennial herbs from deeply seated roots, spreading by rhizomes; growing and flowering with sufficient soil moisture any time of year except the coldest months. Open area of playa. *Reina-G. 96-210 & Van Devender*; *Salywon et al. 999* (ASU); *Turner 95-18.*

Sphaeralcea ambigua A. Gray subsp. **ambigua**. Desert globemallow. Perennial subshrubs; flowering various seasons, especially spring; flowers orange. Seasonally abundant at playa margins, and occasional on sand flats at northeast side of dunes. *Felger 98-21 et al.*; *Turner s.n, 19 Apr 1998.*

Sphaeralcea coulteri (S. Watson) A. Gray var. **coulteri**. Annual globemallow; *mal de ojo*. Non-seasonal annuals, generally growing with winter-spring rains, highly variable in size, several cm to 1.5 m tall; flowers orange. Seasonally abundant, lower dunes including swales, and sand flats. *Felger 98-75 & Evans*; *Turner 95-17.*

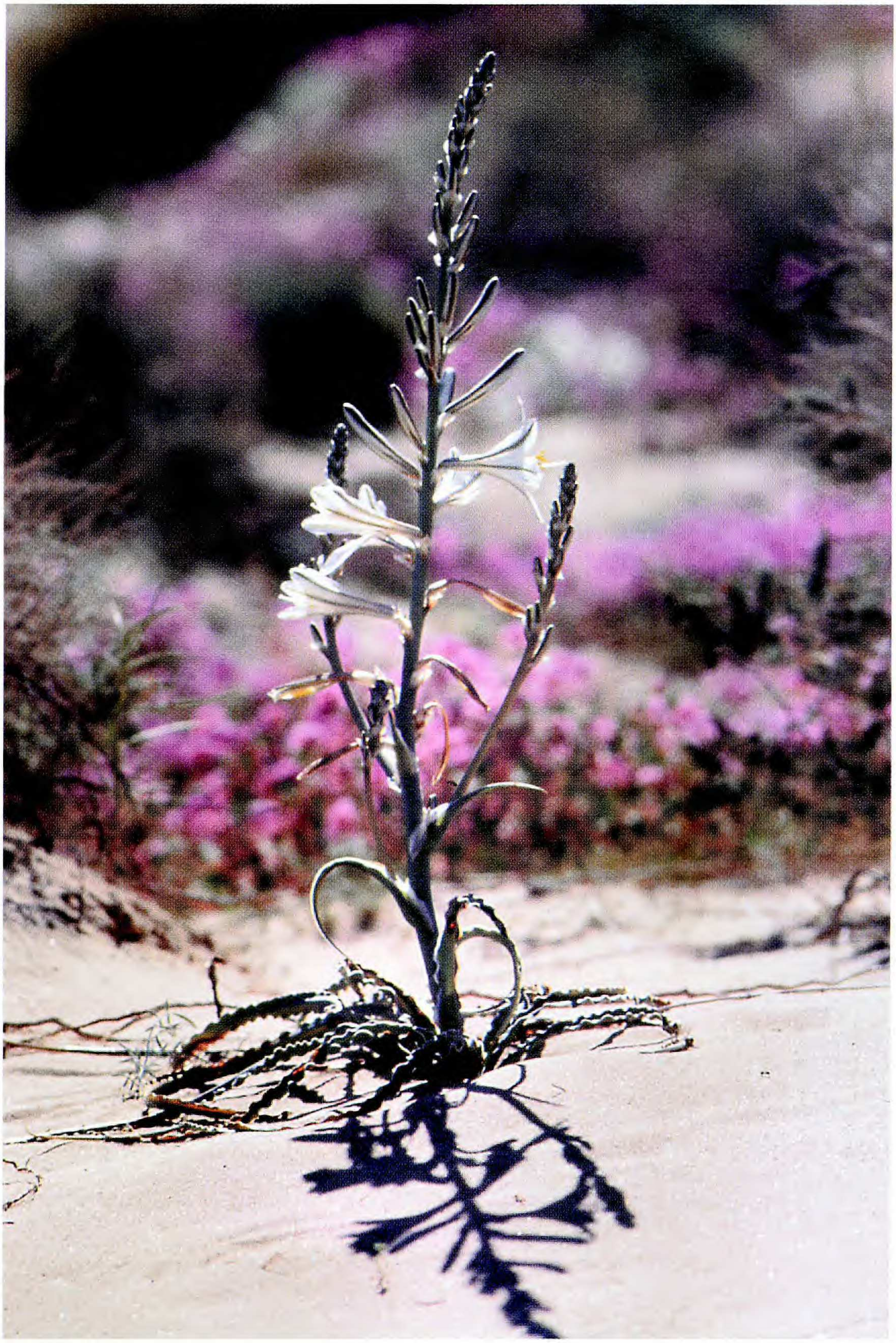

Fig. 12. *Hesperocallis undulata*, flowers ca. 6–7 cm long, April 1998; note the lower leaves in a basal rosette close to the sand. Photo by Charles Hedgcock.

MARTYNIACEAE - Devil's Claw Family

Proboscidea altheaefolia (Benth.) Decne. Devil's claw; *gato, uña de gato, torito*. **Fig. 13.** Perennial herbs from a single tuberous root, growing and flowering during warmer months; flowers showy, bright yellow with white and orange markings. Widely scattered; dunes, sand flats, and playa. *Felger 97-63 et al.; Felger 96-146 & Turner.*

MOLLUGINACEAE - Carpetweed Family

*__Mollugo cerviana__ (L.) Sér. Thread-stem carpetweed; Indian chickweed. Small, hot-weather annuals; flowers minute, green and whitish. Seasonally common on dunes. *Felger 97-62 et al., 97-81.*

NYCTAGINACEAE - Four-O'clock Family

Abronia villosa S.Watson var. **villosa**. Sand verbena. Cool-season annuals; flowers lavender-pink and fragrant. Widespread and often seasonally abundant on dunes and sand hummocks across the Mohawk Valley, often producing spectacular floral displays in spring. *Salywon et al. 996* (ASU); *Turner 95-15.*

Allionia incarnata L. Trailing windmills, trailing four o'clock. Non-seasonal annuals, mostly growing during warmer months, with trailing stems (elsewhere short-lived perennials); violet-rose or magenta. Dunes and sand flats. *Felger 97-54 et al.; Felger 96-132 & Turner.*

Boerhavia erecta L. var. **intermedia** (M.E. Jones) Kearney & Peebles [*B. intermedia* M.E. Jones; *B. triqueta* S.Watson]. Spiderling. Hot-weather annuals; flowers white to pale pink. Sand flats. *Felger 97-75 et al.*

Boerhavia spicata Choisy [*B. spicata* var. *palmeri* S.Watson; *B. coulteri* (Hook.f.) S.Watson]. Hot-weather annuals; flowers white to pale pink. Sand flats and dunes; sometimes very common. The plants are often ravaged by white-lined sphinx moth caterpillars (*Hyles lineata*). *Felger 97-55 et al.; Felger 96-166 & Turner.*

Boerhavia wrightii A. Gray. Largebract spiderling. Hot-weather annuals; flowers pinkish white to pink. Sand flats, often localized in small depressions. *Felger 97-76 et al.*

ONAGRACEAE - Evening Primrose Family

Camissonia boothii (Douglas) P.H. Raven subsp. **condensata** (Munz) P.H. Raven. Woody bottle-washer. Cool-season annuals; flowers white. Skeletons may persistent for one year or more. Mostly in localized colonies on sand flats and occasionally at the playa edge. *Felger 98-92 & Evans; Felger 96-157 & Turner.*

Camissonia californica (Torr. & A. Gray) P.H. Raven. Cool-season annuals; flowers yellow, changing to orange and drying pink. Localized in dune swales and sometimes on sand flats, especially along small washes. *Felger 98-87 & Evans.*

Camissonia chamaenerioides (A. Gray) P.H. Raven. Longcapsule evening-primrose. Cool-season annuals; flowers pink. Sand flats, generally along small washes or in shallow depressions. This is the smallest-flowered evening primrose in the Sonoran Desert; the floral structure and modifications are characteristic of self-pollinated flowers. *Felger 98-100 & Evans.*

Camissonia claviformis (Torr. & Frém.) P.H. Raven subsp. **peeblesii** (Munz) P.H. Raven. Cool-season annuals. Corollas white to pink with maroon-brown inside the tube. Sand flats, lower dunes, dune swales and slopes. *Felger 98-14 et al.; Felger 98-94 & Evans; Turner 95-31.*

Camissonia claviformis subsp. **yumae** (P.H. Raven) P.H. Raven. Cool-season annuals. Corollas yellow with maroon-brown inside the tube. Sand flats near the dune field. *Felger 98-94 & Evans.* Although two subspecies occur in the area, they apparently do not occur intermixed and plants with intermediate features have not been found.

Oenothera deltoides Torr. & Frém. subsp. **deltoides**. Dune evening-primrose, white evening-primrose, devils' lantern. Cool-season annuals; flowers large and white. The dry skeletons persist for one or more years. Sand flats and dunes. Often common and showy. *Turner 95-8.*

Oenothera primiveris A. Gray subsp. **primiveris**. Yellow desert evening-primrose. Cool-season annuals; flowers large and yellow. The dry skeletons may persist for several years. Mostly lower dunes, also swales

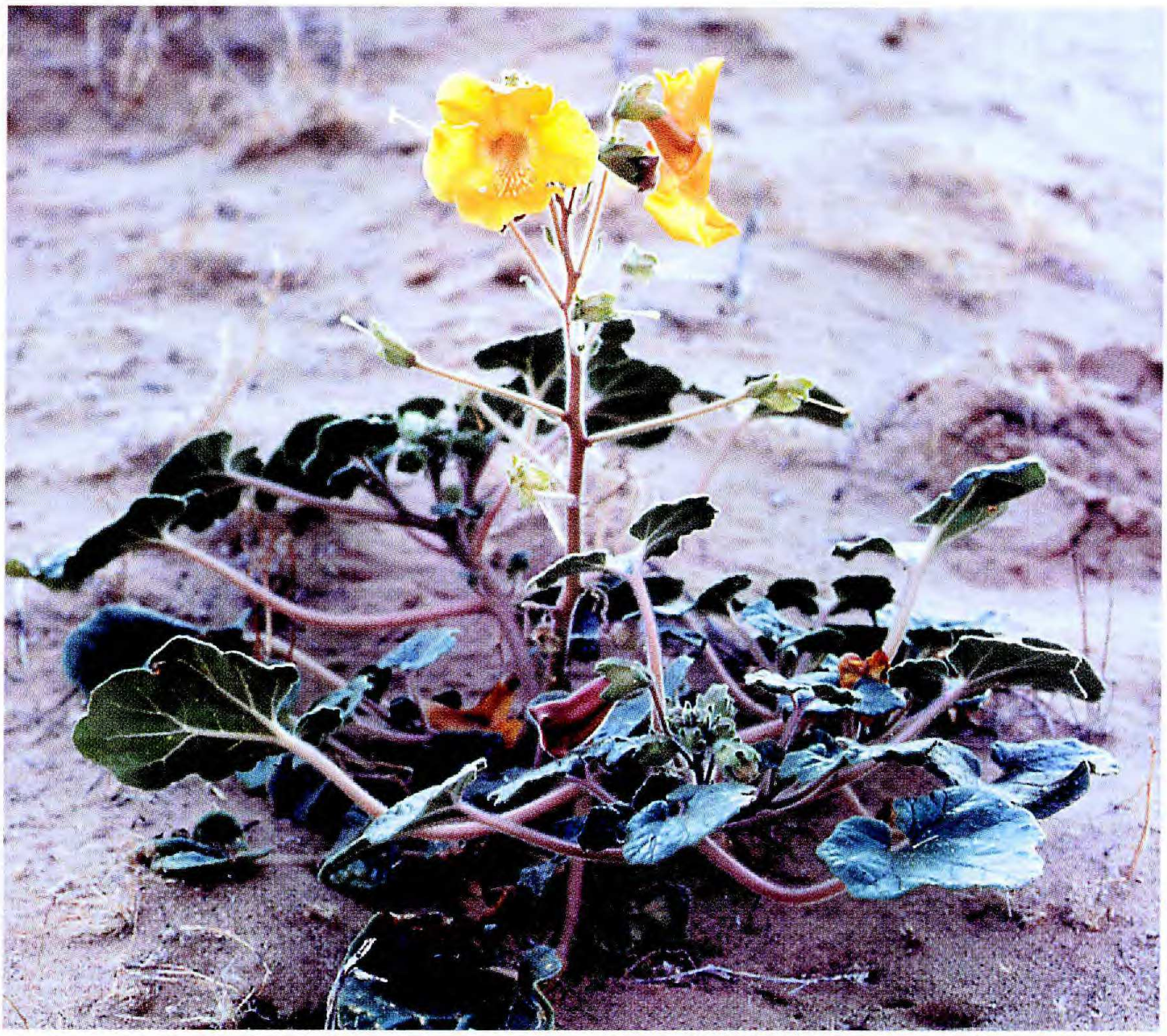

FIG. 13. *Proboscidea altheaefolia*, dunes, August 1996. Photo by Charles Hedgcock.

and sand flats. *Felger 98-84 & Evans; Felger 96-158 & Turner.*

OROBANCHACEAE - Broomrape Family

Orobanche cooperi (A. Gray) A. Heller. Desert broomrape; *flor de tierra*. Cool-season annuals parasitic on *Ambrosia* spp.; stems thick and succulent; flowers purple and white, the throat often marked with yellow. Although the plants may appear perennial because of their robust habit, they are apparently annuals (George Yatskievych, pers. comm.). Sand flats. *Goldberg 77-91; Turner s.n., 2 May 1998.*

PAPAVERACEAE - Poppy Family

Argemone gracilenta Greene. Sonoran pricklypoppy, fried-egg poppy; *cardo*. Short-lived perennials to 80+ cm tall, or probably often facultative annuals in the flora region; flowering late spring and in nearby areas sometimes sporadically through the summer; flowers large, with white petals and numerous yellow stamens. Lower dunes and dune swales, scattered and seldom common. *Felger 98-77 & Evans.*

Eschscholzia glyptosperma Greene. Gold poppy. Cool-season annuals. Locally common during years of exceptional winter-spring rain; flowers yellow-orange. Sand flats, especially near the northern and eastern part of the dune field. *Felger 98-88 & Evans; Salywon et al. 982* (ASU); *Turner 95-23.*

Eschscholzia minutiflora S. Watson. Little gold-poppy. Cool-season annuals; flowers yellow-orange. Dunes and locally on sand flats. *Turner 95-33.*

PLANTAGINACEAE - Plantain Family

Plantago ovata Forssk. [*P. insularis* Eastw., not *P. insularis* (Grenier & Godron) Nyman; *P. fastigiata* E. Morris; *P. insularis* var. *fastigiata* (E. Morris) Jeps.]. Woolly plantain, Indianwheat; *pastora*. Winter-spring ephemerals, highly variable in size depending on soil moisture; flowers straw-colored. Widespread across dunes and sand flats, but especially lower dunes and swales, and sometimes on the playa. *Felger 98-1 et al.; Goldberg 77-88; Salywon et al. 998* (ASU); *Turner 95-19.*

POACEAE (GRAMINEAE) - Grass Family

Aristida adscensionis L. Sixweeks threeawn; *zacate tres barbas*. Non-seasonal annuals. Sand flats. *Felger 96-145 & Turner.*

Aristida californica Thurb. var. **californica**. California threeawn; *tres barbas de california*. Tufted perennials, also flowering in first season during summer. Widespread, sand flats and especially common on dunes. *Felger 98-10 et al.; Felger 96-142 & Turner, 96-167, 96-170.*

Bouteloua aristidoides (Kunth) Griseb. Sixweeks needle grama; *aceitilla, navajita*. Summer annuals. Sand flats and dunes; widespread and common. *Felger 97-80 et al., 97-67; Felger 96-140 & Turner.*

Bouteloua barbata Lag. Six-weeks grama; *navajita, zacate liebrero*. Summer annuals. Sand flats and dunes. *Felger 97-68 et al.; Felger 96-131 & Turner, 96-131.*

Festuca octoflora Walter [*Vulpia octoflora* (Walter) Rydb.; *F. octoflora* var. *hirtella* Piper]. Sixweeks fescue, eight-flowered fescue. Cool-season annuals; diminutive grass. Sand flats, mostly beneath shrubs and in small depressions at the northeast side of the dune field. *Felger 98-97 & Evans.*

Muhlenbergia microsperma (DC.) Trin. Littleseed muhly; *liendrilla chica*. Non-seasonal annuals. Generally beneath shrubs in small washes or depressions in sand flats. *Felger 98-18 et al.*

Panicum alatum Zuloaga & Morrone var. **minus** (Andersson) Zuloaga & Morrone. Summer annuals. Shallow depression in sand flats at edge of playa. *Felger 98-8 et al.* This species is indistinguishable from the common and widespread *P. hirticaule* except for consistent spikelet characters. In western Sonora and southwestern Arizona *P. alatum* has a limited and localized distribution, characteristically in playas and similar habitats with temporary standing water and clayish soils, while *P. hirticaule* is widespread and common in many habitats throughout the region (Felger 2000). They do not seem to occur together.

Pleuraphis rigida Thurb. [*Hilaria rigida* (Thurb.) Benth. ex Scribn.]. Big galleta; *galleta grande, toboso*. Large, tufted or bushy perennials. Widespread and abundant, dunes and sand flats. *Felger 96-137 & Turner.*

*__Schismus arabicus__ Nees. Arabian schismus. Cool-season annuals. Widespread and seasonally abundant on sand flats and dunes, and especially common on dune slopes and swales. The plants at first grow close to the ground, apparently preventing the growth of native ephemerals (see Felger 2000). *Turner 95-11.*

POLEMONIACEAE - Phlox Family

Eriastrum diffusum (A. Gray) H. Mason. Cool-season annuals; flowers pale blue. Dunes and sand flats. *Felger 98-55 & Evans.*

Eriastrum eremicum (Jeps.) H. Mason. Cool-season annuals; flowers dark blue. Sand flats. This is the southwestern record for this species, and the only plant in the Mohawk flora not in the Gran Desierto or near the Pinta Sands or Yuma Dunes. *Burgess 5059; Turner 95-32.*

Linanthus bigelovii (A. Gray) Greene [*Gilia bigelovii* A. Gray, 1870; *Gilia jonesii* A. Gray, 1886; *Linanthus bigelovii* var. *jonesii* (A. Gray) Brand; *L. jonesii* (A. Gray) Greene]. Cool-season annuals. Flowers white, nocturnal, opening at or near dusk and powerfully sweet-fragrant, sometime nauseously sweet, and closing before sunrise. Dunes including swales and sand flats. *Bowers 2993; Felger 98-54 & Evans; Reichenbacher 273.*

Linanthus jonesii is distinguished by glandular-stipitate calyces (sometimes quite densely so) and seeds constricted near the middle (appearing "pinched off"), whereas *L. bigelovii* sensu stricto is distinguished by glabrous calyces and a bladdery, ellipsoid seed. However, in southwestern Arizona the variation seems continuous, the characters do not seem correlated with each other, there appears to be no discernable correlation with habitat or geography, and they do not seem to be distinct taxa.

Loeseliastrum schottii (Torr.) Timbrook [*Langloisia schottii* (Torr.) Greene]. Winter-spring annuals. Scattered, mostly in swales and sand flats, sometimes extending to higher dunes, seldom common. *Felger 98-53 & Evans; Goldberg 77-83; Turner 95-34.*

POLYGONACEAE - Buckwheat Family

Chorizanthe brevicornu Torr. subsp. **brevicornu**. Brittle spineflower, short-horn spineflower. Cool-season annuals; flowers white and minute. Dunes, especially swales, dune slopes, and lower dunes; also on sand flats. *Felger 98-81 & Evans.*

Chorizanthe rigida (Torr.) Torr. & A. Gray. Rigid spineflower. Cool-season annuals; the dry skeletons persistent for several years; flowers white, minute and cryptic. Common and widespread on sand flats. *Felger 98-9 et al.; Felger 98-89 & Evans; Reichenbacher 271.*

Eriogonum trichopes Torr. var. **trichopes**. Little trumpet. Cool-season annuals, occasionally surviving the summer; flowers yellow. Dunes and sand flats. *Felger 98-57 & Evans; Salywon et al. 989* (ASU).

Nemacaulis denudata Nutt. var. **gracilis** Goodman & L.D. Benson. Woolly heads. Cool-season annuals; Flowers minute, yellow, surrounded by yellow-green to white and pink woolly bracts. Mostly in dune swales, also lower to higher dunes. *Felger 98-73 & Evans; Salywon et al. 990* (ASU).

RESEDACEAE - Mignonette Family

Oligomeris linifolia (Vahl) J.F. Macbr. Desert cambess, slenderleaf cambess. Non-seasonal annuals; flowers inconspicuous, white and green. Playa, sand flats, and lower dunes. *Turner 95-20.*

SALICACEAE - Willow Family

Populus fremontii S. Watson subsp. **fremontii**. Cottonwood; *alamo*. Several saplings along the southern edge of the playa. Apparently they grew during the El Niño year of 1992-1993, and were still living by end of April 1994, having reached 2-2.5 m tall, but perished by the end of 1994. *Felger 96-153 & Turner; Phil Rosen,* 24 Apr 1994, photo.

SIMAROUBACEAE - Quassia Family

Castela emoryi (A. Gray) Moran & Felger [*Holacantha emoryi* A. Gray]. Crucifixion thorn; *corona de cristo*. Shrubs 2-3 m tall; May-July; flowers cream-yellow to pink; fruits densely clustered and persistent. Scattered on sand flats, and also lowermost dunes surrounding the playa. *Felger 96-162 & Turner; Reina-G. 96-216 & Van Devender.*

SOLANACEAE - Nightshade Family

Datura discolor Bernh. Poisonous nightshade, desert thorn-apple; *toloache*. Non-seasonal annuals, the plants frost-sensitive; flowers 8-17 cm long, corollas white with a purple flush in the throat, nocturnal and fragrant. Sand flats and probably on dunes. This is the largest-flowered plant in the region. *Felger & Turner*, 25 Sep 1996, observation.

Lycium parishii A. Gray var. **parishii**. Parish wolfberry; *salicieso*. Shrubs; reproductive at various seasons, especially late winter and early spring; corollas lavender. Washes in sand flats near north end of dunes. *Felger 98-20 et al.*

Physalis lobata Torr. [*Quincula lobata* (Torr.) Raf.]. Annual or perennial herbs with a deep tap root; flowers lavender, after sufficient rains at various seasons. Locally at the playa margins. *Felger 98-51 & Evans; Turner 95-29.*

TAMARICACEAE - Tamarisk Family

*__Tamarix ramosissima__ Ledeb. [*T. chinensis* of American authors, not Lour.?]. Saltcedar, tamarisk; *salado, pino salado*. One shrub at the southwest edge of the playa, first seen May 1995, and by June 1996 it had perished from drought. *Felger & Turner*, 25 Sep 1996, observation.

VISCACEAE - Mistletoe Family

Phoradendron californicum Nutt. Desert mistletoe; *tóji.* Epiphytic perennial parasites; flowers small, green or yellow, at various seasons, especially January and February; highly fragrant and attracting honeybees and other insects; fruiting in same season. On widely scattered mesquite trees on sand flats. *Felger & Turner*, 24 Sep 1996, observation.

ZYGOPHYLLACEAE - Caltrop Family

Kallstroemia californica (S. Watson) Vail. California caltrop; *mal de ojo.* Hot-weather annuals; flowers yellow to yellow-orange. Sand flats and dunes. *Felger 97-58 et al.; Felger 96-129 & Turner, 96-133, 96-160.*

Larrea divaricata Cav. subsp. **tridentata** (Sessé & Moç. ex DC.) Felger & C.H. Lowe [*L. tridentata* (Sessé & Moc. ex DC.) Cov.]. Creosotebush; *hediondilla, gobernadora.* Long-lived shrubs ca. 1–2 m tall with very hard wood; flowers yellow, various seasons. Dominant shrub or "canopy" across most of the sand flats and valley floor surrounding the dunes, and extending onto lower dunes and dune swales.

ACKNOWLEDGMENTS

For financial support we thank the Wallace Research Foundation, and the 56th Range Management Office of Luke Air Force Base for funding this work under Contract FO260497MS130 and under the Department of Defense Legacy Resource Management Program (Project 95-1009). We thank Bill Broyles, Luke Evans, Julia Fonseca, Scotty Johnson, Cecil Schwalbe, Gerald Turner, Louise Turner, and Peter Warren for generous assistance and Charles Hedgcock (www.charleshedgcock.com) and Thomas R. Jones for supplying photos. James Henrickson, Wendy Hodgson, and John Anderson provided significant reviews. Phil Jenkins and Michael Chamberland of the University of Arizona herbarium greatly facilitated our work, and Andrew Salywon and Tom Van Devender shared significant information.

REFERENCES

Bowers, J.E. 1982. The plant ecology of inland dunes in western North America. J. Arid Environm. 5:199–220.

Bowers, J.E. 1984. Plant geography of southwestern sand dunes. Desert Plants 6:31–42,51–54.

Bowers, J.E. 1986. Seasons of the Wind: a naturalist's look at the plant life of southwestern sand dunes. Northland Press, Flagstaff.

Broyles, B., R.S. Felger, G.P. Nabhan, and L. Evans. 1997. Our grand desert: a gazetteer for northwestern Sonora, southwestern Arizona, and northeastern Baja California. J. Southwest 39:703–855.

Felger, R.S. 1980. Vegetation and flora of the Gran Desierto, Sonora, Mexico. Desert Plants 2:87–114.

Felger, R.S. 2000. Flora of the Gran Desierto and Río Colorado of northwestern Mexico. University of Arizona Press, Tucson.

Felger, R.S., A. Harlan, V.W. Steinmann, and F.W. Telewski. 1993. *Cryptantha ganderi* I.M. Johnston (Boraginaceae); new for Arizona. Madroño 40:268.

Felger R.S., M. Wilson, B. Broyles, and G.P. Nabhan. 1997. The Binational Sonoran Desert Biosphere Network and its plant life. J. Southwest 39:411–560.

HICKMAN, J.C. (ed.). 1993. The Jepson manual. University of California Press, Berkeley.

KEARNEY, T.H. and R.H. PEEBLES. 1960. Arizona flora. 2nd edition with supplement by J.T. Howell and E. McClintock. University of California Press, Berkeley.

LEHTO, E. 1979. "Extinct" wire-lettuce, *Stephanomeria schottii* (Compositae), rediscovered in Arizona after more than one hundred years. Desert Plants 1:22.

SELLERS, W.D. and R.H. Hill (eds.). 1974. Arizona climate, 1931–1972. 2nd edition. University of Arizona Press, Tucson.

SELLERS, W. D., R.H. HILL, and M. SANDERSON-RAE (eds.). 1985. Arizona climate: the first hundred years. University of Arizona Press, Tucson.

SHREVE, F. 1951. Vegetation of the Sonoran Desert. Carnegie Institution of Washington Publication no. 591.

SMITH, L.E. and G.L. BENDER. 1973. Proposed natural areas, report no. 12: Mohawk sand dunes and mountains. Report to the Planning Division, Department of Economic Planning and Development, Office of the Governor, State of Arizona.

THORNE, R.T., B.A. PRIGGE, and J. HENRICKSON. 1981. A flora of the higher ranges and the Kelso Dunes of the Eastern Mohave Desert in California. Aliso 10:71–186.

TUNNICLIFF, B., S.K. BRICKLER, et al. (Natural Resources Planning Team). 1986. Natural Resources Management Plan for Luke Air Force Range. School of Renewable Natural Resources, College of Agriculture, University of Arizona. Tucson.

TURNAGE, W.V. and T.D. MALLERY. 1941. An analysis of rainfall in the Sonoran desert and adjacent territory. Carnegie Institution of Washington publication 529.

TURNER, D.S., C.R. SCHWALBE, and P.L. WARREN. 1997a. Reptile and plant inventory of the Mohawk Dunes, Barry M. Goldwater Air Force Range, Arizona. Contract report to Luke Air Force Base, Legacy Resource Management Program, Project 95–1009.

TURNER, D.S., C.R. SCHWALBE, and P.L. WARREN. 1997b. Reptile and plant monitoring plan; inventory and monitoring of unique sand dune ecosystems, Barry M. Goldwater Air Force Range, Arizona. Contract report to Luke Air Force Base, Legacy Resource Management Program, Project 95–1009.

VASCULAR PLANTS OF ARIZONA EDITORIAL COMMITTEE. 2001. A new flora for Arizona in preparation. J. Arizona-Nevada Acad. Sci. 33:i–ii.

VENABLE, D.L. and C.E. PAKE. 1999. Population ecology of Sonoran Desert annual plants. In: R.H. Robichaux, ed. Ecology of Sonoran Desert plants and plant communities, University of Arizona Press, Tucson. Pp. 115–142.

WARREN, P.L. and A.W. LAURENZI. 1987. Rare plant survey of the Yuma District. Final report of P.O. No. AZ-950-PH6-0540, U.S. Bureau of Land Management, Yuma District Office.

WESTEC SERVICES. 1977. Survey of sensitive plants of Algodones Dunes. Report to U.S. Department of Interior, Bureau of Land Management, Riverside, CA.

WIGGINS, I.L. 1964. Flora of the Sonoran Desert. In: F. Shreve and I.L. Wiggins. Vegetation and flora of the Sonoran Desert, 2 vols. Stanford University Press, Stanford. Pp. 189–1740.

WILSON, M.F., L. LEIGH, and R.S. FELGER. 2002. Invasive exotic plants in the Sonoran Desert. In: B. Tellman, ed. Invasive Exotic Species in the Sonoran Region. University of Arizona Press, Tucson. Pp. 81–90.